Gluon Polarization via Open Charm Production at $\vec{e}\vec{p}$ collider

Jörg Pretz

Physikalisches Institut, Universität Bonn

GSI, May 2009

1 Introduction

Introduction

Nucleon Spin Decomposition

$$\frac{1}{2} = \underbrace{\frac{1}{2}\Delta\Sigma}_{\text{Quarks}} + \underbrace{\Delta G}_{\text{Gluons}} + \underbrace{L_q}_{\text{Quarks}} + \underbrace{L_g}_{\text{Gluons}}$$

Spin (Quarks, Gluons) — orbital angular momentum (Quarks, Gluons)

Nucleon Spin Decomposition

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

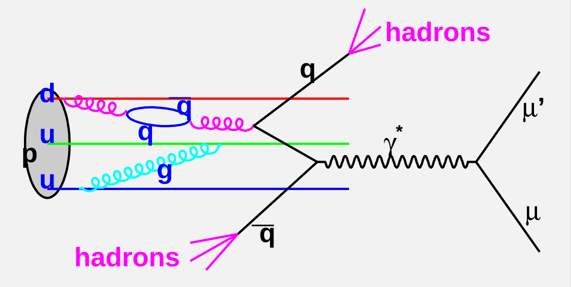
$\frac{1}{2}\Delta\Sigma$	ΔG	L_q	L_g
Spin		orbital angular momentum	
Quarks	Gluons	Quarks	Gluons

$\Delta\Sigma$ only ≈ 0.3 ! Expected ≈ 0.6. One possibility to solve this "spin puzzle" would require large gluon contribution $\Delta G = \int_0^1 \Delta g(x)\mathrm{d}x = 2 - 3$.

How to access the gluon distribution?

Use hadronic final state in deep inelastic scattering:

$$\vec{\mu} + \vec{N} \rightarrow \mu' + \text{hadrons} + X$$



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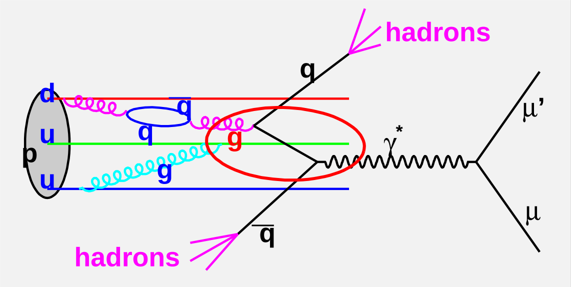
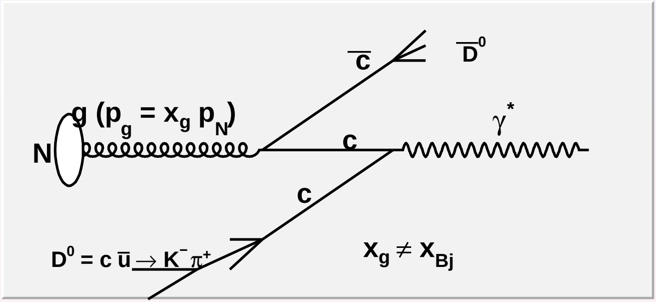


How to tag Photon -Gluon- Fusion sub-process
$\gamma^* g \rightarrow q\bar{q}$?

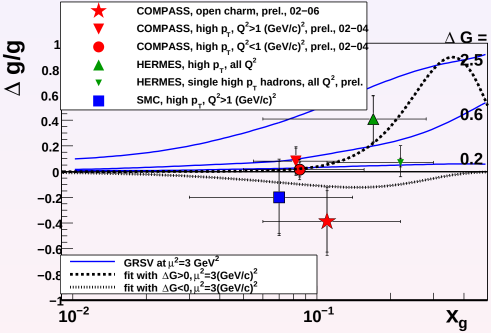
How to tag $\gamma^* g \to q\bar{q}$?

Cleanest way: Look at charmed particles resulting from the fragmentation of the process $\gamma^* g \to c\bar{c}$:



- no intrinsic charm,
- no charm quarks in string fragmentation
- If both charmed particles are reconstructed, one has access to x_g

Results on Δg from DIS



- Data show small values of $\Delta g/g$ at $x_g \approx 0.1$
- confirmed by indirect measurements
  - Scaling violation of $g_1^{p,n,d}$ structure function
  - $\vec{p}\vec{p}$ scattering at RHIC
- all measurements are concentrated around $x_g = 0.1$, little is known about $\Delta g(x_g)$

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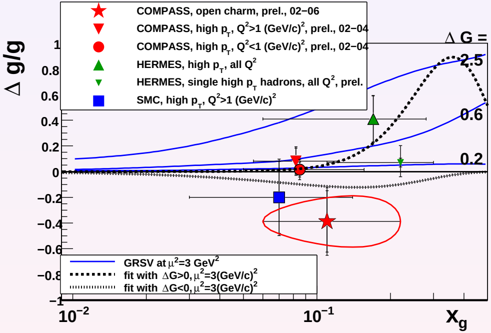

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- all measurements are concentrated around $x_g = 0.1$, little is known about $\Delta g(x_g)$
- only COMPASS point is obtained with the (least model dependent) open charm method
- this result is obtained in $\approx$ 200 days of running

FOM:

Luminosity & Diluting Factors

Luminosity

Luminosity:

	COMPASS	collider
Lumi	$0.3 \cdot 5 \cdot 10^{32}/\mathrm{cm}^2/\mathrm{s}$	$2 \times 10^{32}/\mathrm{cm}^2\mathrm{s}$

Gain: $2/(0.3 \cdot 5) = \mathbf{1.3}$

Diluting Factors

Diluting factors:

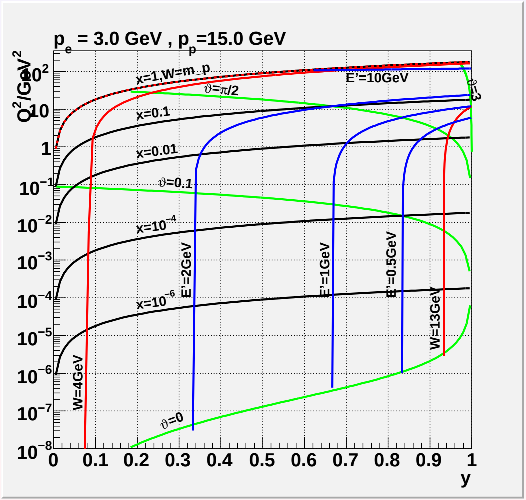
	COMPASS	collider
P_T	0.5	0.8
P_B	0.8	0.8
f	0.4	1
$(P_T P_B f)^2$	0.026	0.41

Gain: $0.41/0.026 =$ **16**

FOM:

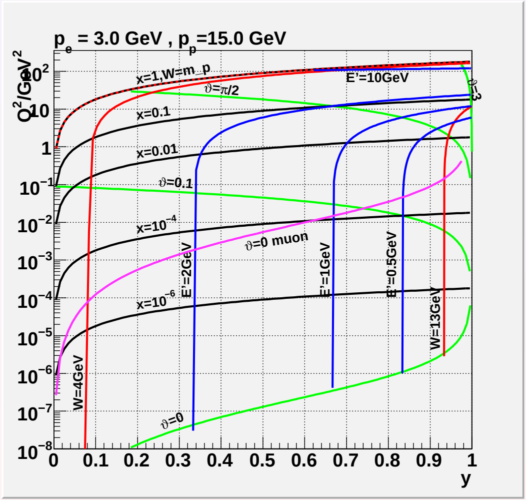
Photon Flux

Kinematic Region



- Playground in $Q^2 - y$ plane $(\mathrm{Pol}(\gamma^*) \approx \mathrm{y})$

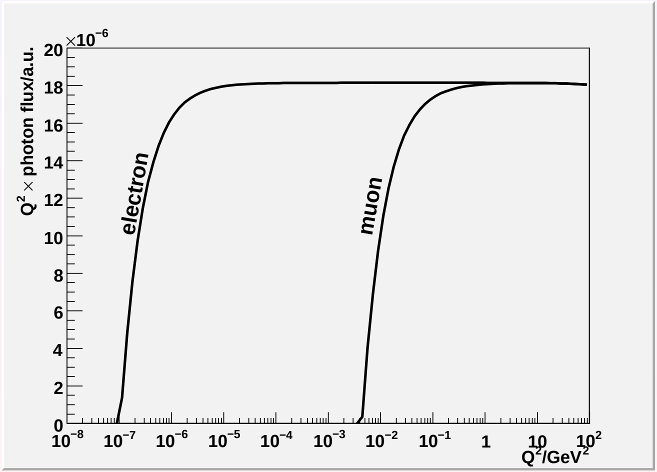
Kinematic Region



- Playground in $Q^2 - y$ plane $(\mathrm{Pol}(\gamma^*) \approx \mathrm{y})$
- Higher Q^2_{min} for μ

Advantage e over μ

$Q^2\times$ photon flux vs. Q^2 (for $y = 0.5$)



Gain due to higher photon flux $\approx$ **2**.

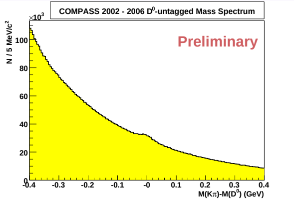
FOM:

D^0 meson reconstruction

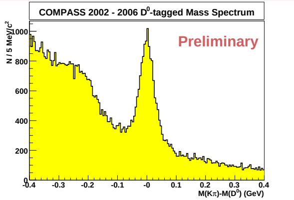
D^0 reconstruction

COMPASS

$D^0 \to K^-\pi^+ + c.c \quad (37\text{k } D^0)$



D^0 from $D^{*+} \to D^0 + \pi^+$
$\to K^-\pi^+\pi^+ \quad (9\text{k } D^0)$



collider

S:B = 4:1

(expected for PANDA)

assume B=0

D^0 reconstruction

	COMPASS S:B	collider S:B	
D^0	1:10	4:1	
D^*	1:1	1:0	

D^0 reconstruction

	COMPASS S:B	collider S:B	Gain in FOM*
D^0	1:10	4:1	11
D^*	1:1	1:0	2.6

In COMPASS D^0 and D^* have approximately the same FOM:
$\Rightarrow$ total gain $\approx \frac{11+2.6}{2} =$ **7**

* for the same number of signal events

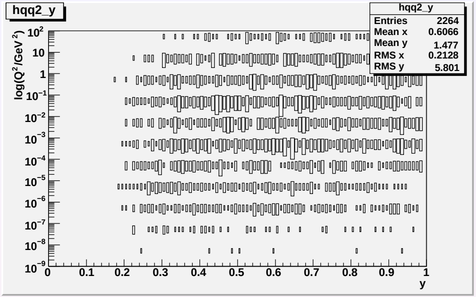
D^0 reconstruction

- COMPASS has a solid state target:
  - $\Rightarrow$ D^0 decay vertex cannot be resolved from main vertex
  - $\Rightarrow$ mass resolution deteriorated due to multiple scattering
- Additional gains at collider:
  - from number of reconstructed D mesons (COMPASS target has ≈ 1 nuclear interaction length)
  - considering more decay channels ($D^0 \to K^- \pi^+$ has only 4% BR)

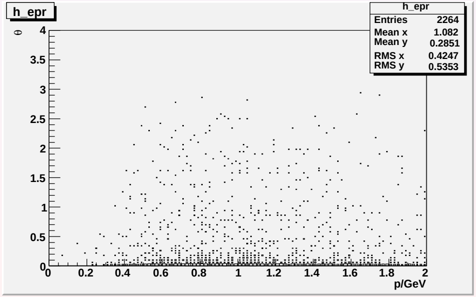
Gain in FOM

source	factor
LUMI	1.3
$(fP_T P_B)^2$	16
photon flux	2
eff. D^0 signal	> 7
total	$\approx$ **300**

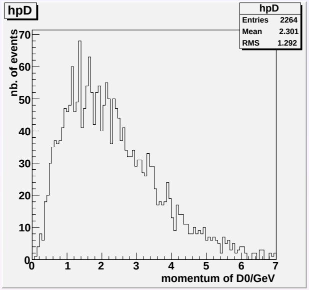
Kinematic Distributions & Range



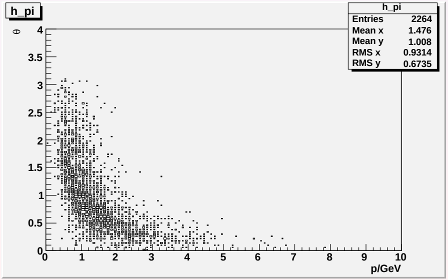
distribution of events in $Q^2 - y$ plane from PYTHIA MC



scattered electron: in θ vs. p



D^0 momentum



decay pion:
θ vs. p

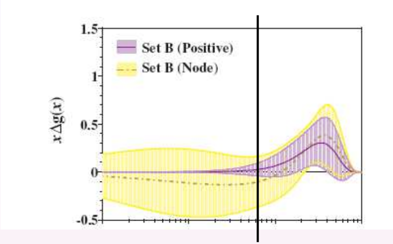
gluon momentum fraction range covered

Lower limit:

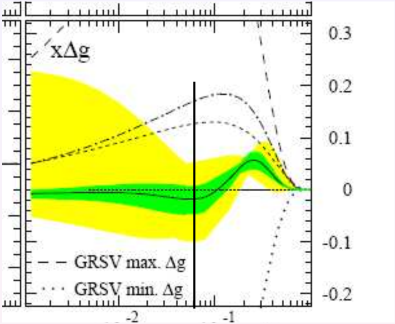
$$x_g(min) = \frac{4m_c^2}{s}$$

COMPASS $E = 160$ GeV	pol eNC $E_p = 15$ GeV, $E_e = 3$ GeV
s/GeV^2	
300	180
$x_g(min)$	
0.02	**0.038**

QCD analysis on $\Delta g(x)$



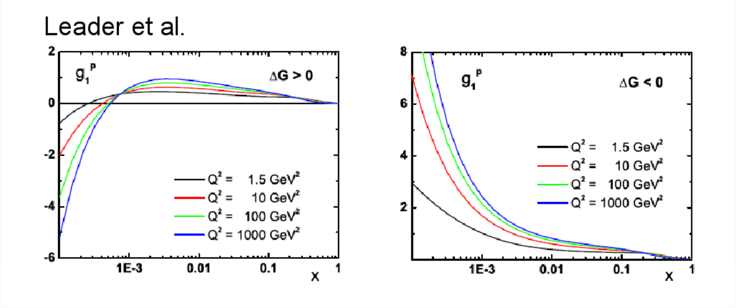
Hirai, Kumano



de Florian, Sassot, Stratmann, Vogelsang

- largest error in the region $x_g < 0.1$
- RHIC covers and will cover $0.01 < x_g < 0.2$

Structure function $g_1(x)$ for different Q^2



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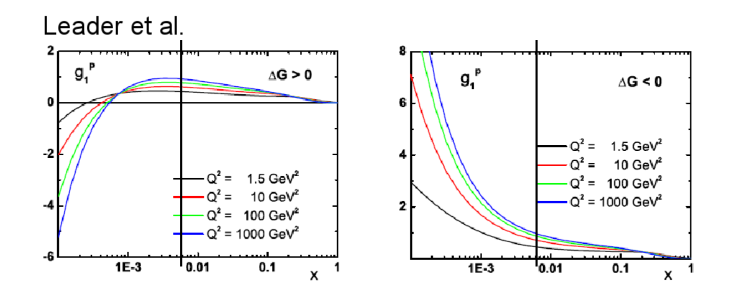


$$x_{Bj}(min) = \frac{1}{Ms}$$

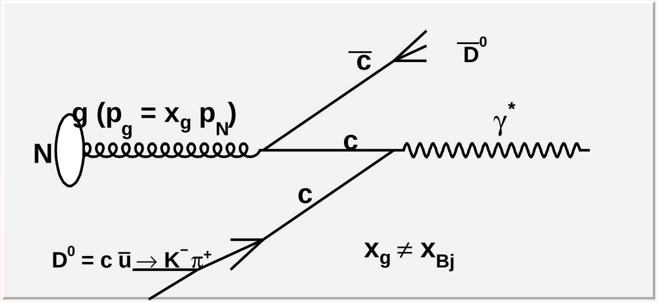
$$Q^2 > 1\text{GeV}^2$$

COMPASS $E = 160$ GeV	pol eNC $E_p = 15$ GeV, $E_e = 3$ GeV
s/GeV^2	
300	180
$x_{Bj}(min)$	
0.0036	0.0059

Qualitative Improvements

Qualitative differences

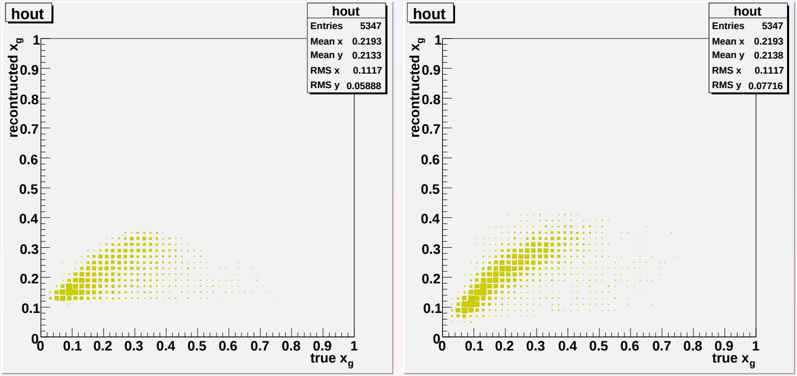
- In COMPASS only one of the two D mesons produced in a event is reconstructed
  $\Rightarrow$ momentum fraction x_g of gluon cannot be reconstructed
- Collider: Possibility to reconstruct both D mesons in one event
  $\Rightarrow$ better access to gluon momentum fraction x_g
- $\Rightarrow$ measurement of $\Delta g/g(\mathbf{x_g})$ is possible and not only $< \Delta g/g >_{x_g}$



Better Reconstruction of x_g

using information of ...

... one D^0 (52% corr.) ... both D^0 (70% corr.)



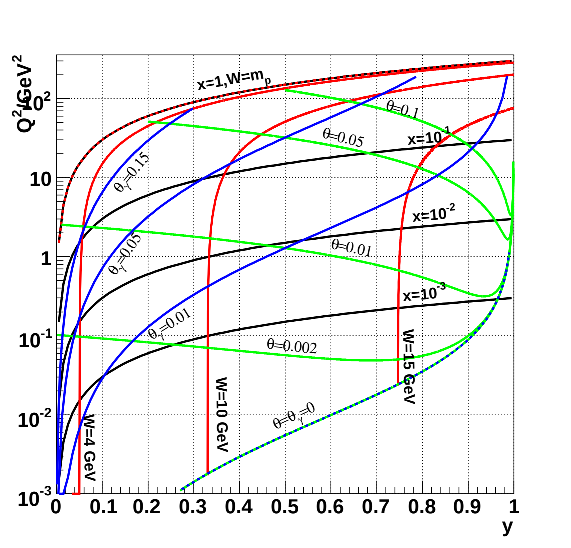
Summary & Outlook

Summary

Measurement of $\frac{\Delta g}{g}(\mathbf{x_g})$ via open-charm at collider looks very promising!

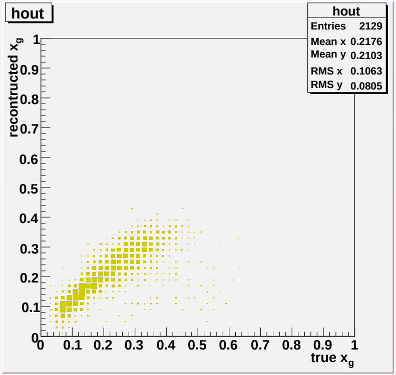
Spare

Kinematic Region for COMPASS ($p_\mu = 160$ GeV)



Better Reconstruction of x_g

$z > 0.3$ 76% corr.



$z > 0.4$ 85% corr.