Measurement of the Gluon Polarization in the Nucleon at COMPASS

Jörg Pretz

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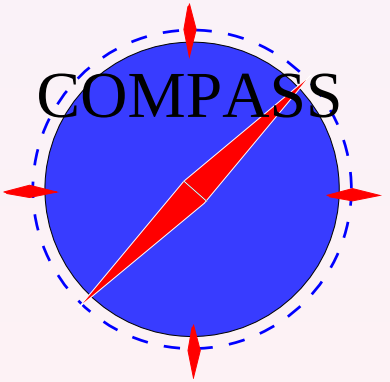
on behalf of the
COMPASS collaboration



QCD Montpellier, July 2008

1 Motivation: Nucleon Spin Puzzle

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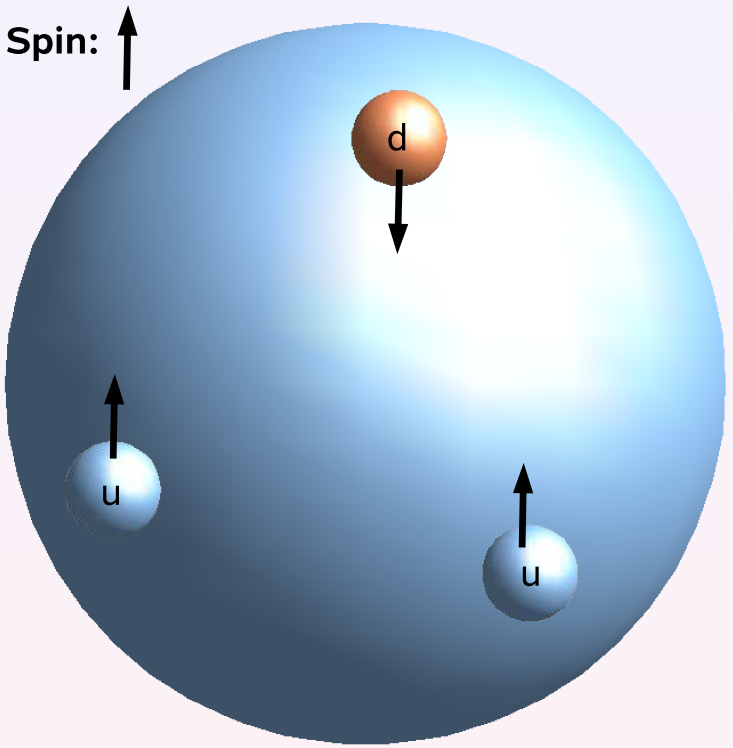
Proton Spin Structure . . .



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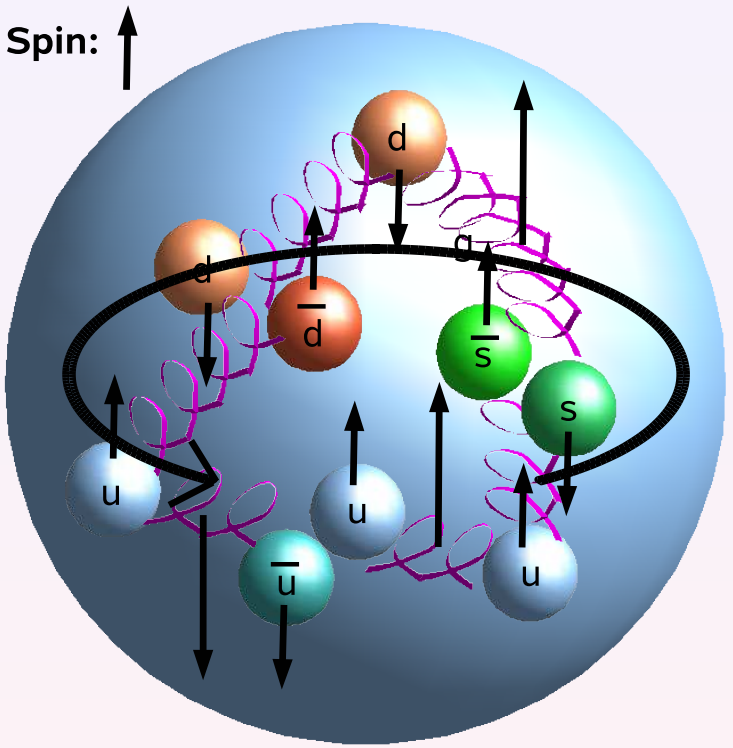

- . . . looks simple in static quark model
- . . . much more complicated in QCD

Nucleon Spin Decomposition

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

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Spin

orbital angular momentum

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

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Focus in this talk:

Helicity Contribution of Gluons, ΔG, to the nucleon spin!

How to access the Gluon distribution?

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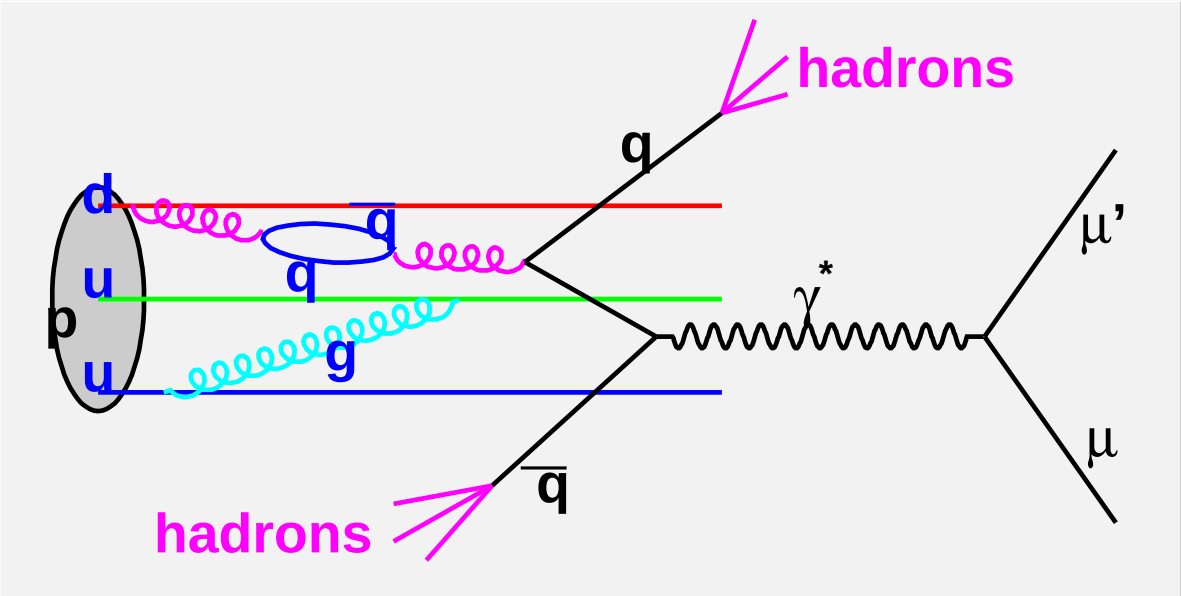
Use hadronic final state in deep inelastic scattering:

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



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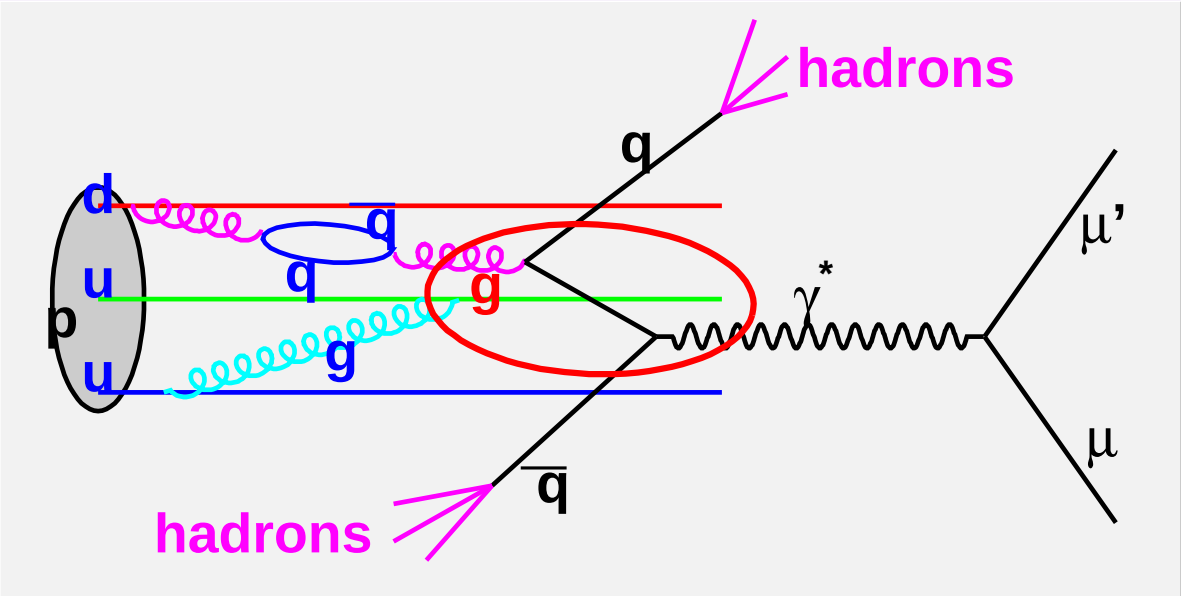
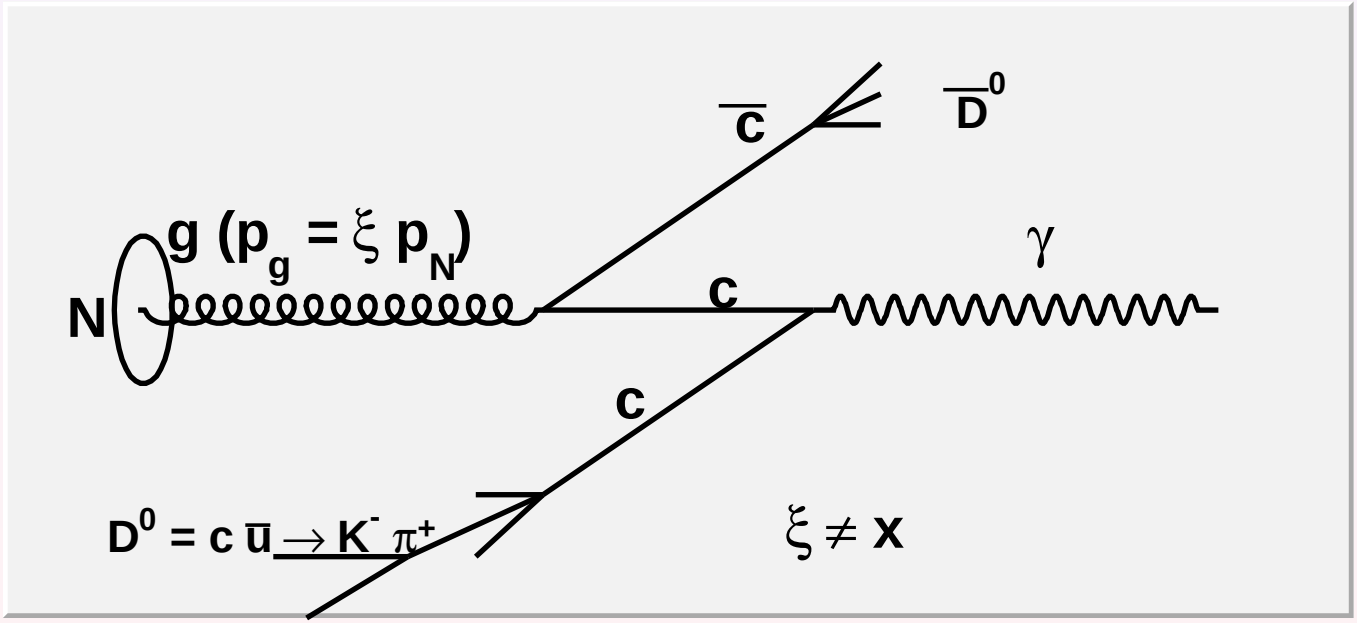


How to tag Photon -Gluon- Fusion sub-process

$$\gamma^* g \rightarrow q\bar{q} \ ?$$

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

hadrons	advantage	disadvantage
open charm	clean tag*	low statistics
high p_T hadron (pairs)	higher statistics	background processes



* no intrinsic charm, no charm quarks in string fragmentation

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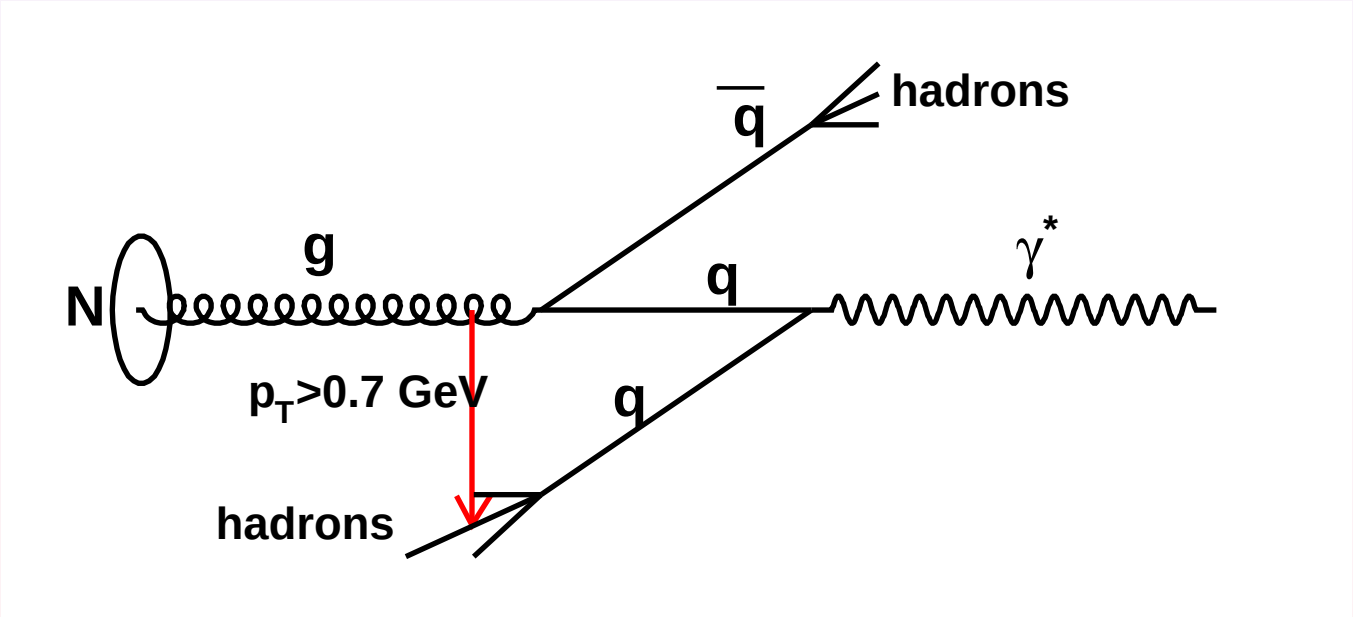

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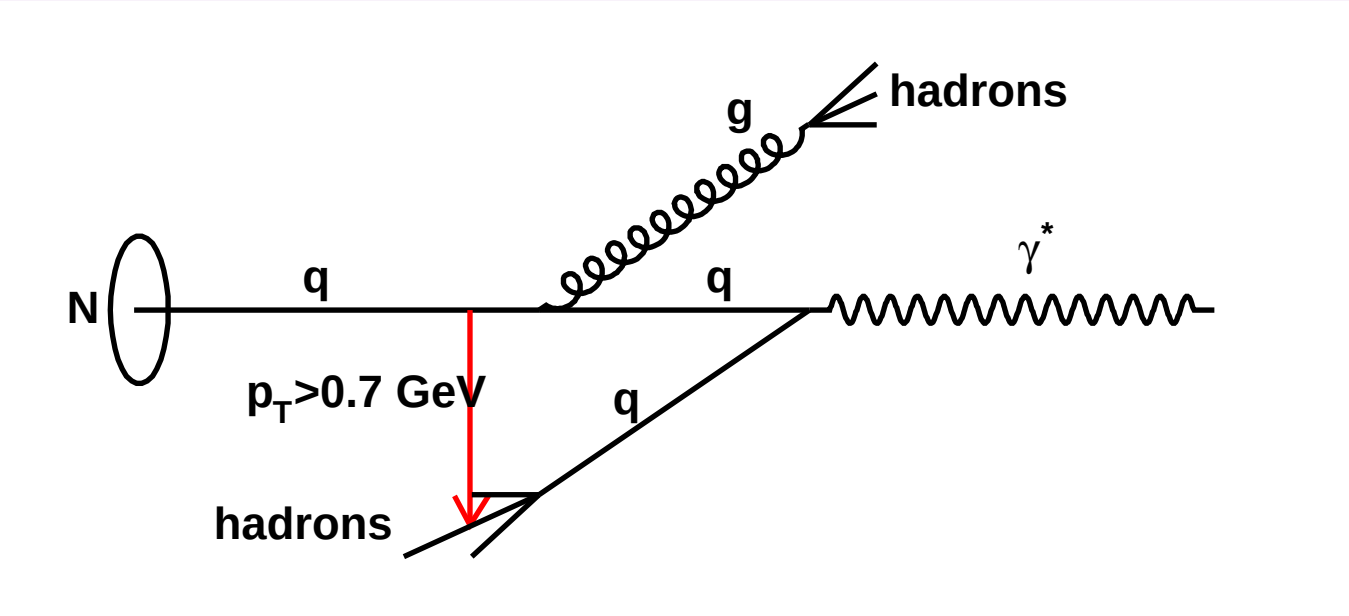

QCD Compton process one of background processes

How to measure ΔG

- To tag gluon look at
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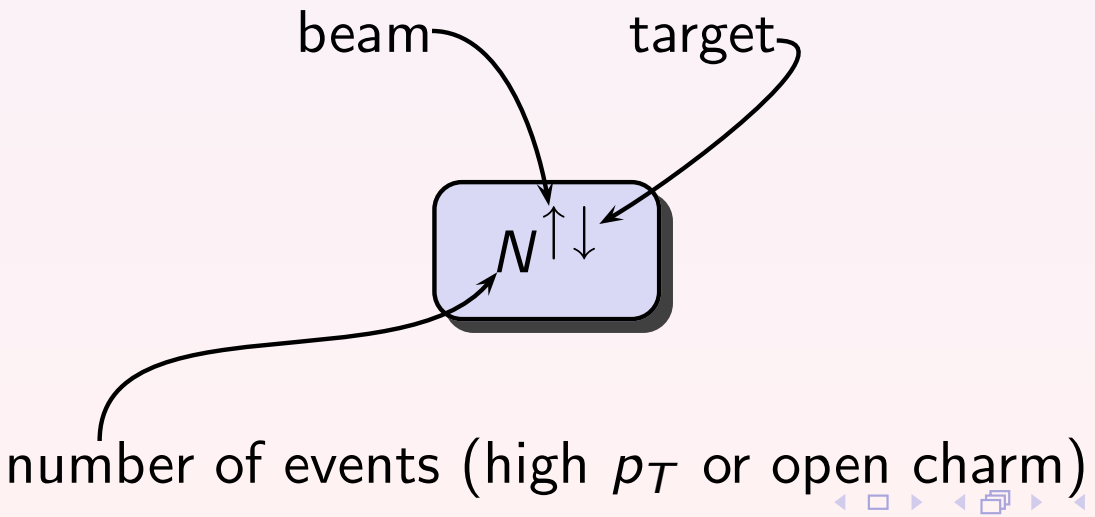
- To tag gluon look at
  - charmed hadrons or
  - hadrons with large transverse momentum
- To learn something about spin, measure double spin asymmetries

$$A^{raw} = \frac{N^{\uparrow\downarrow} - N^{\uparrow\uparrow}}{N^{\uparrow\downarrow} + N^{\uparrow\uparrow}} \propto \frac{\Delta G}{G}$$



High p_T $\leftrightarrow$ open charm

$$A^{raw} = \frac{N^{\uparrow\downarrow} - N^{\uparrow\uparrow}}{N^{\uparrow\downarrow} + N^{\uparrow\uparrow}} = P_B\, P_T\, f\, a_{LL} \frac{\sigma_{PGF}}{\sigma_{PGF} + \sigma_{bgd}} \frac{\Delta G}{G} + A^{bgd}$$

	high p_T pairs	open-charm
P_B	beam polarization ≈ -0.8	
P_T	target polarization ≈ 0.5	
f	dilution factor ≈ 0.4 for ^{6}LiD target	
a_{LL}	asymmetry of partonic process $\vec{\mu} + \vec{g} \rightarrow \mu' + q + \bar{q}$	
	≈ -0.6	-0.5 to 0.6
$\frac{\sigma_{PGF}}{\sigma_{PGF} + \sigma_{bgd}}$	fraction of photon-gluon fusion process	
	0.3	0.5(D^*) 0.1 (D^0)
source of background	Compton, resolved photon, ..	combinatorial background
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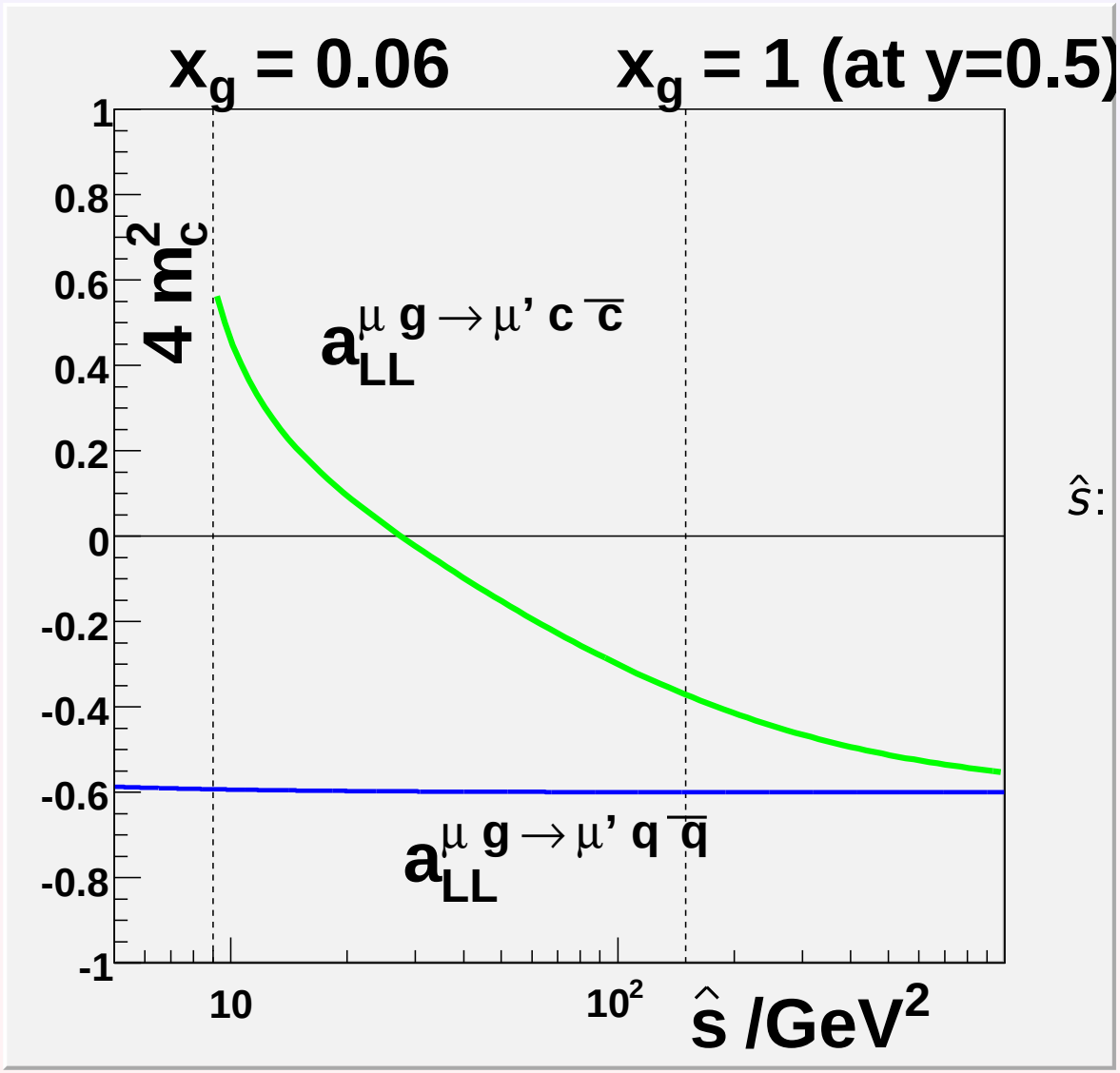

$\hat{s}$: CMS energy of $\gamma^* g$ system

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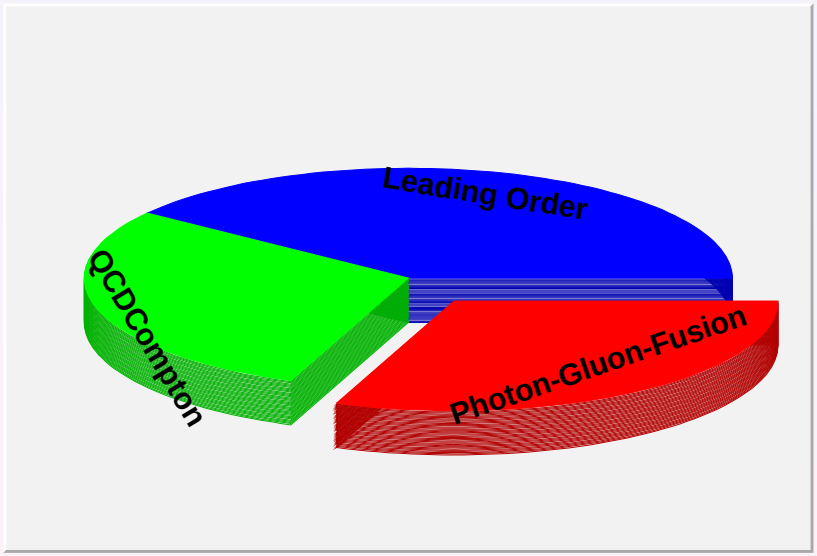
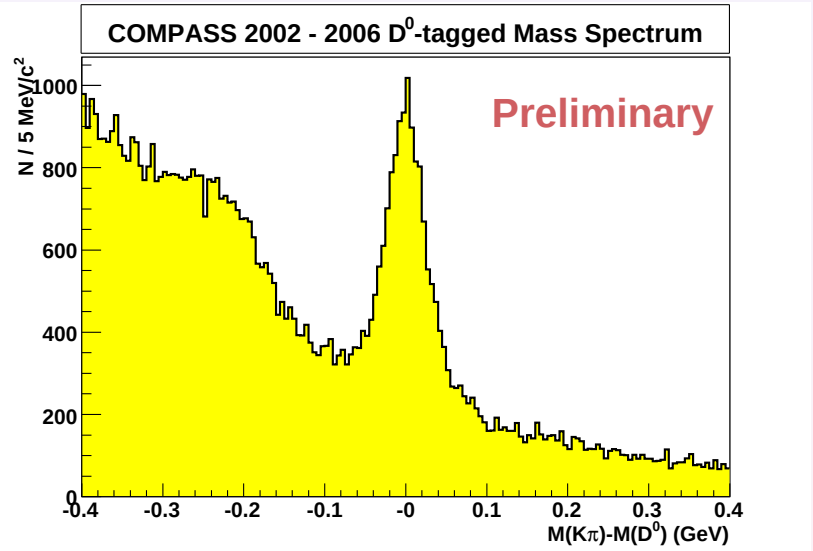


$$R = \frac{\sigma_{PGF}}{\sigma_{PGF}+\sigma_{bgd}} \approx 0.3$$

from LEPTO MC for $Q^2 > 1$ GeV^2
PYTHIA MC for $Q^2 < 1$ GeV^2

Open Charm

$$D^{*+} \rightarrow D^0\pi^+_{soft} \rightarrow K^-\pi^+\pi^+_{soft}$$



$$R = \frac{\sigma_{PGF}}{\sigma_{PGF}+\sigma_{bgd}} \approx 0.5$$

from data

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Highlights of the Analysis

- Open Charm
  - Signal and background asymmetries are extracted simultaneously from mass spectrum,
    more efficient than side band subtraction,
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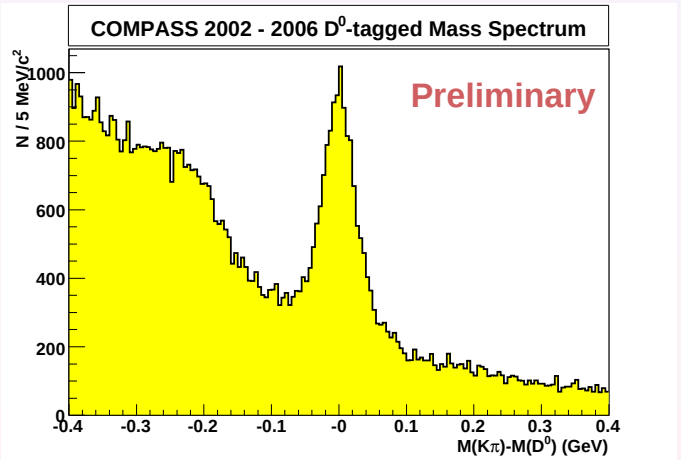

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  - $\frac{\sigma_{PGF}}{\sigma_{PGF}+\sigma_{bgd}}$ is parameterized in terms of 10 variables, not just as a function of the receonstructed mass.
  - each event in addition weighted with a_{LL}, important because a_{LL} has positive and negative value

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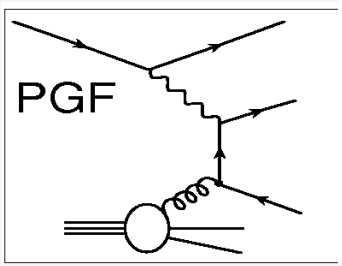

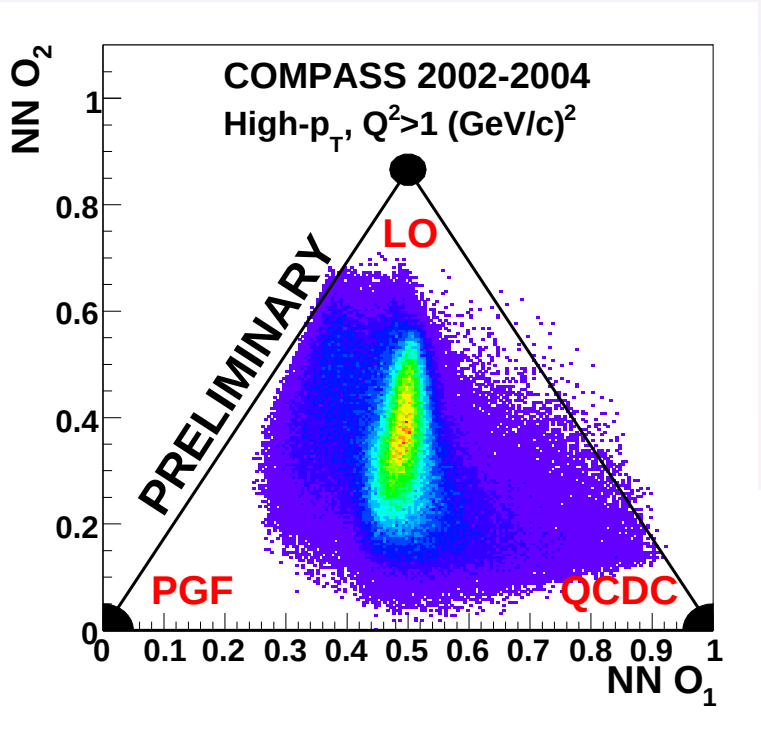

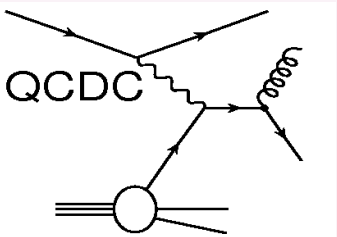

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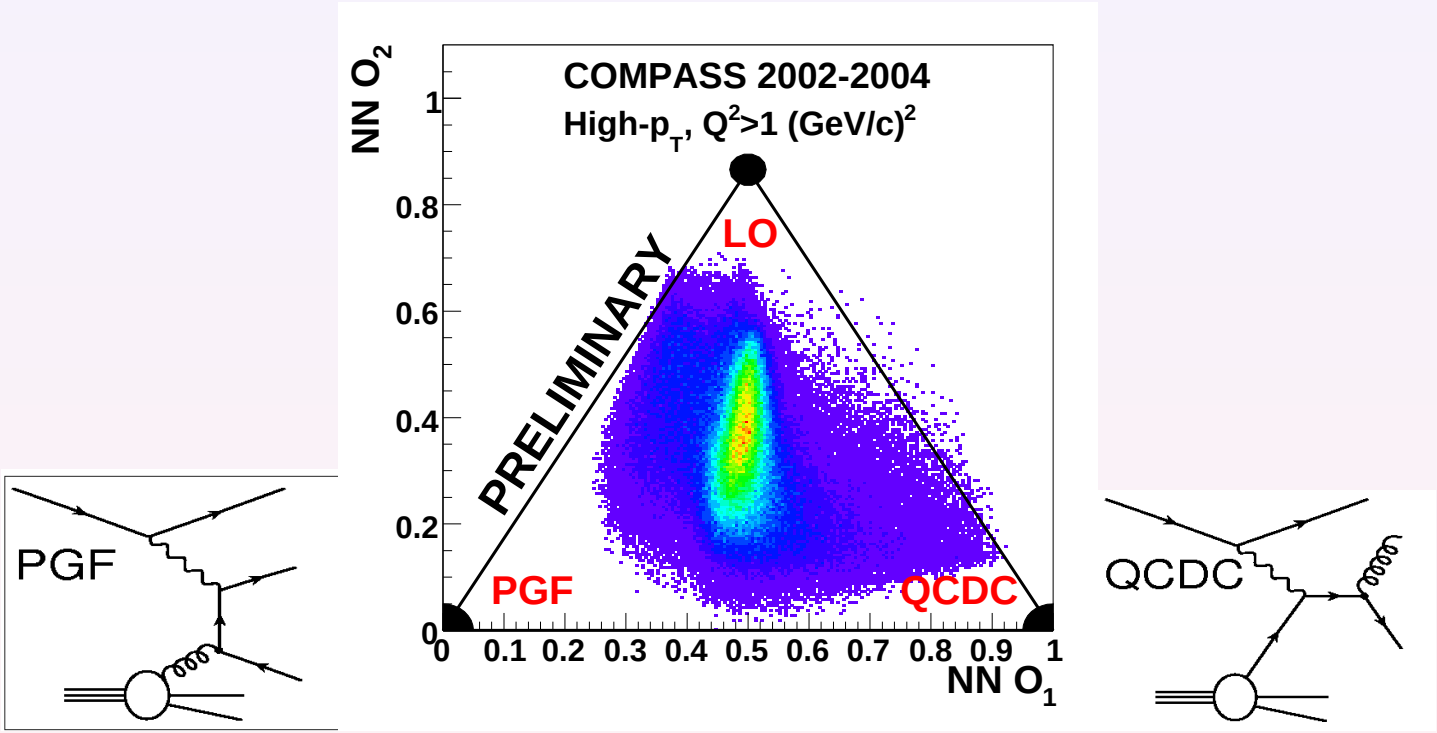
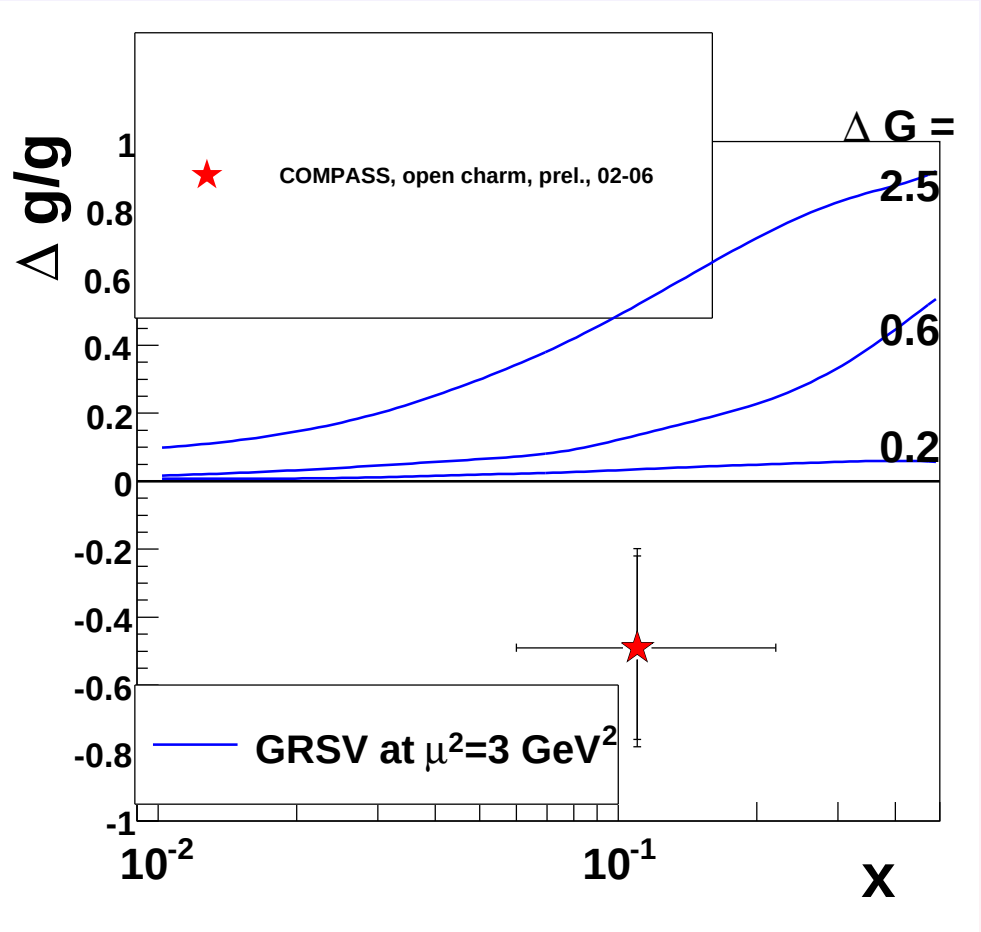


  - every event weighted with a probability to be a PFG event,

Results

Results on ΔG from DIS



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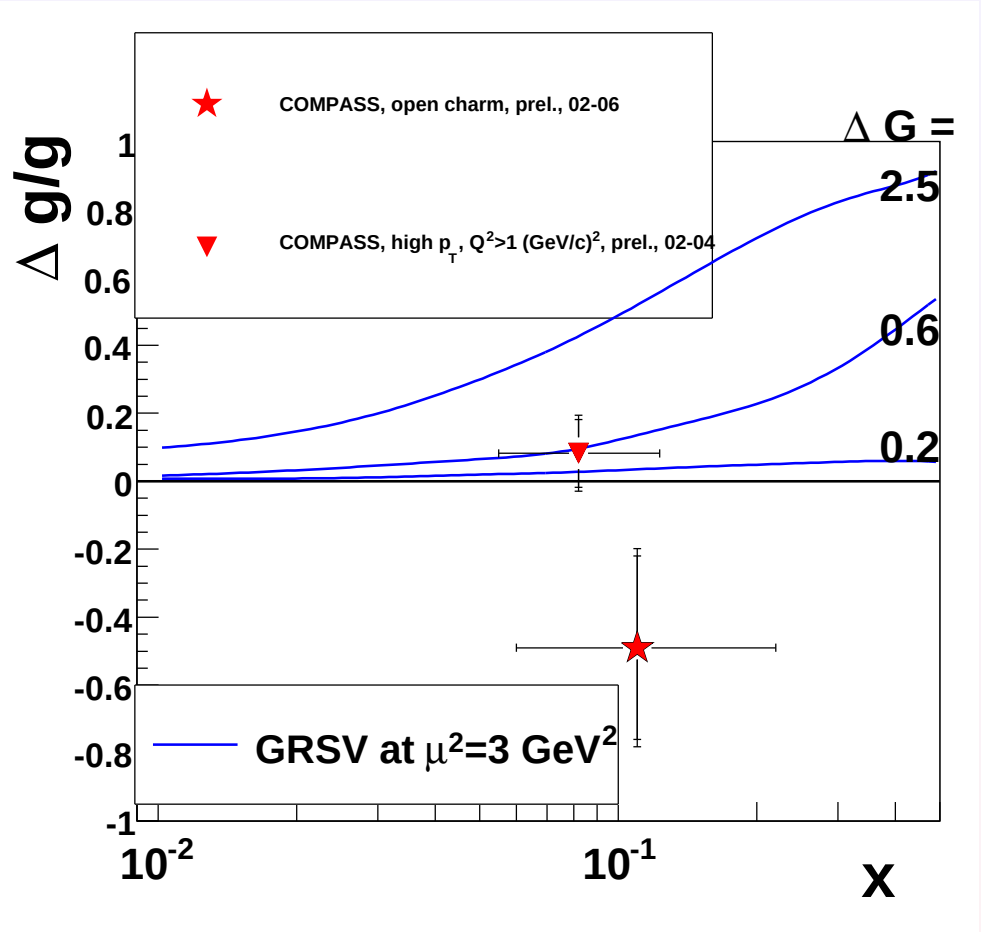

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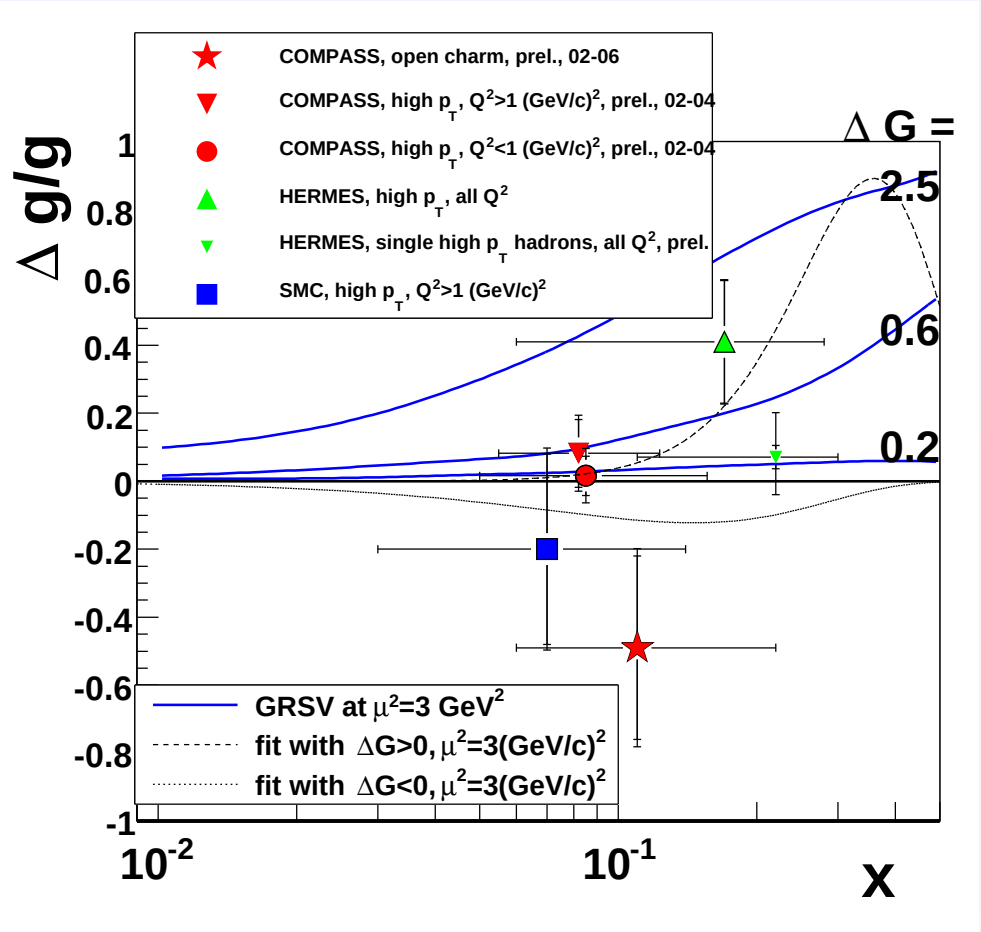

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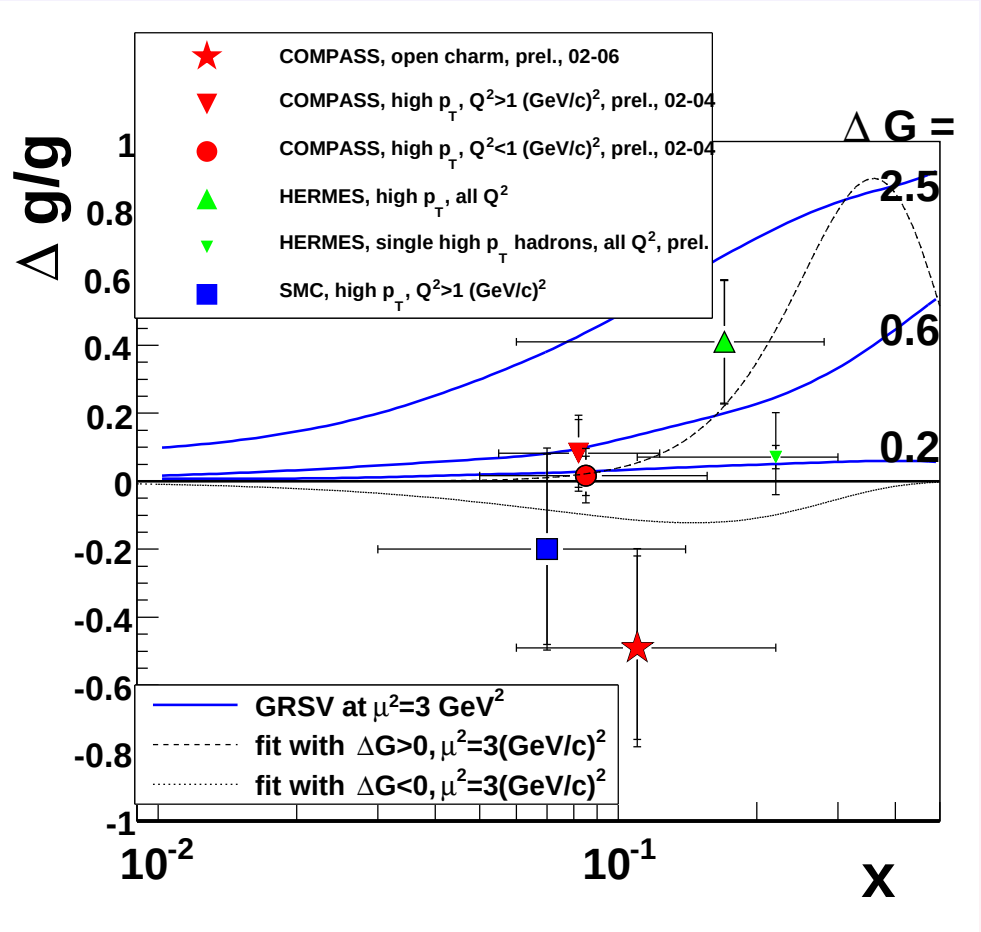

- direct measurement recently released by COMPASS
- Data show small values of $\Delta g/g$ at $x_g \approx 0.1$
- confirmed by indirect measurements
  - Scaling violation of $g_1^{p,n,d}$ structure function
  - $\vec{p}\vec{p}$ scattering at RHIC

Message to theorists

Our results, relies on LO QCD.
COMPASS will also provide muon-nucleon asymmetries for D^0 production:

$$A^{\mu+N\to\mu'+D^0+X} = \frac{\Delta\sigma}{\sigma}$$

- $\Delta\sigma$ (σ) is polarized (unpolarized) muon-nucleon cross sections for D^0 production.
- can be calculated by theorists as a function of $\Delta g(x)$ (and $g(x), q(x)$ fragmentation functions, ...)

Summary

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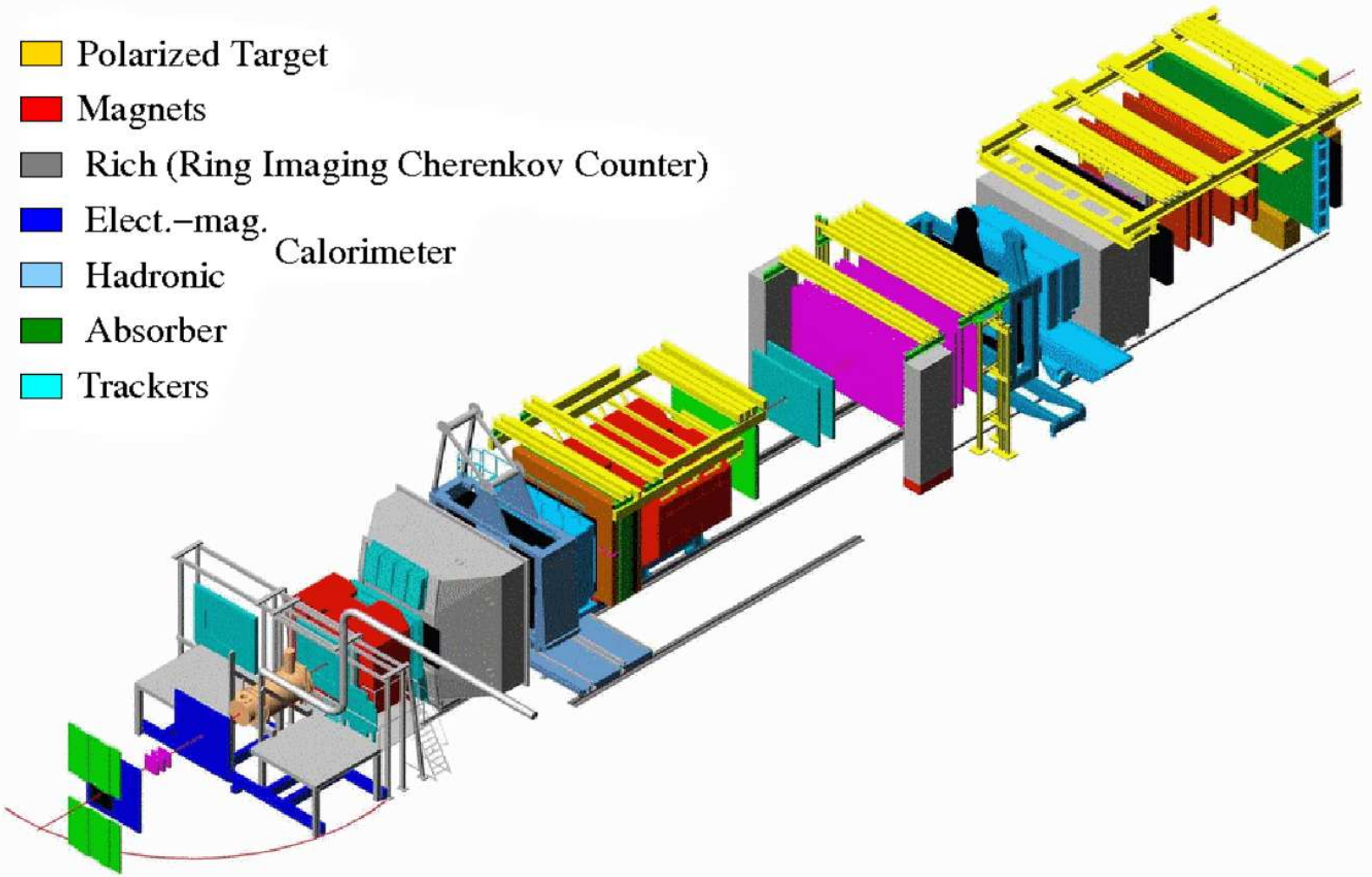
- new results on $\Delta g/g$ from COMPASS
- direct measurements show: $\Delta g/g$ small at $x_g \approx 0.1$
- confirmed by indirect measurements
- Large first moments $\Delta G = \int_0^1 \Delta G(x) dx \approx 2 - 3$ ruled out by data
- $\Delta G = \int_0^1 \Delta G(x) dx \approx \frac{1}{2}$ (gluon carries 100% of nucleon spin) still possible
- shape of $\Delta g(x)$ still not well constrained
- there is more to come ...

SPARE

The COMPASS Experiment



Parameters of Experiment

Spectrometer:	Two stages 1 GeV $< p <$ 200 GeV tracking: Scifis, GEMs , Micromegas, Straws particle id.: K, π separation $9 < p <$ 60 GeV with RICH ECAL,HCAL,μFilter Trigger on μ' and hadrons
Beam:	160 GeV μ , $2 \cdot 10^8$/5s, naturally polarized Pol = –0.80 $\pm$ 0.04
pol. Target:	$2 \times$ 65 cm cells, oppositely polarized ^{6}LiD, Pol $\approx$ 0.5, DNP

Summary: Experiment

- polarized μ beam of 100-200 GeV $\rightarrow$ Deep Inelastic scattering
- polarized target
- Two stage spectrometer
  - momentum range 1-200 GeV
  - particle id.

Fulfills all requirements to study Spin Structure of the Nucleon

The Nucleon Spin Puzzle

Static Quark Model: $\Delta\Sigma = 1$

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Weak Baryon decays: $\Delta\Sigma = 0.58 \pm 0.03$

(Assumption $\Delta s + \Delta\bar{s} = 0$)

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Static Quark Model: $\Delta\Sigma = 1$

Weak Baryon decays: $\Delta\Sigma = 0.58 \pm 0.03$

(Assumption $\Delta s + \Delta\bar{s} = 0$)

pol. DIS: $\Delta\Sigma = 0.30 \pm 0.02$

$\Delta s + \Delta\bar{s} = -0.08 \pm 0.02$

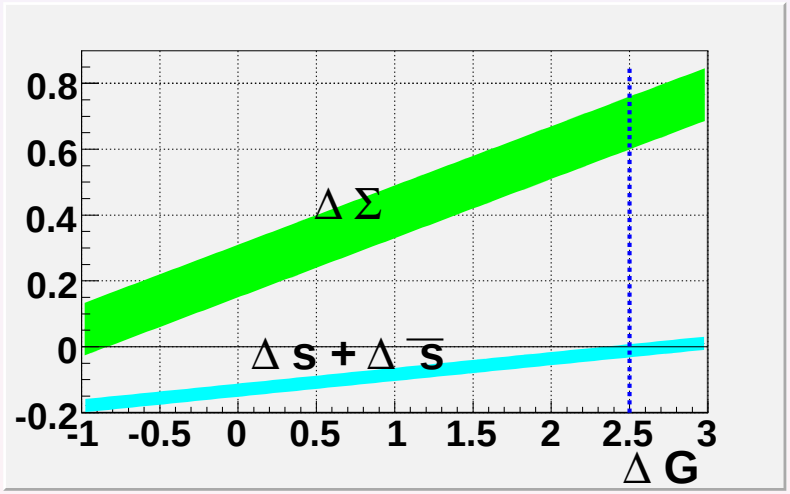
The Nucleon Spin Puzzle

But NLO QCD corrections make interpretation of $\Delta\Sigma$ difficult:

$\Delta\Sigma \rightarrow \Delta\Sigma - \frac{3\alpha_s}{2\pi}\Delta G$, α_s : strong coupling constant

$\Delta s \rightarrow \Delta s - \frac{\alpha_s}{2\pi}\Delta G$

$\Delta G = G^{\uparrow} - G^{\downarrow}$, **polarized gluon distribution**



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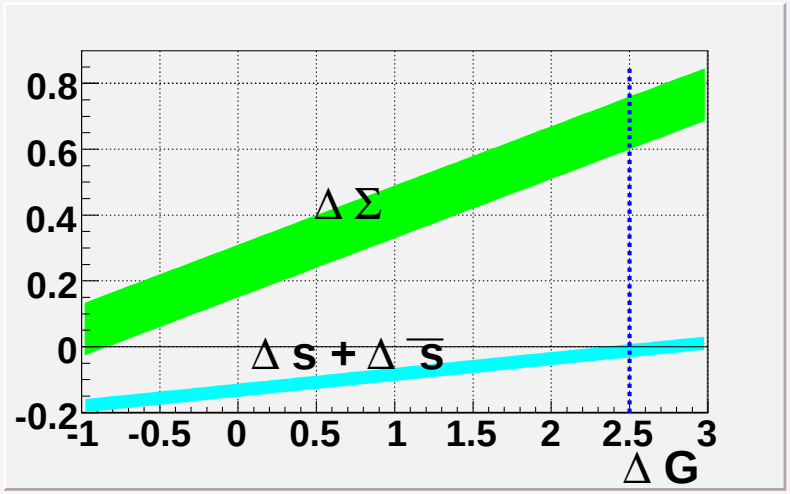


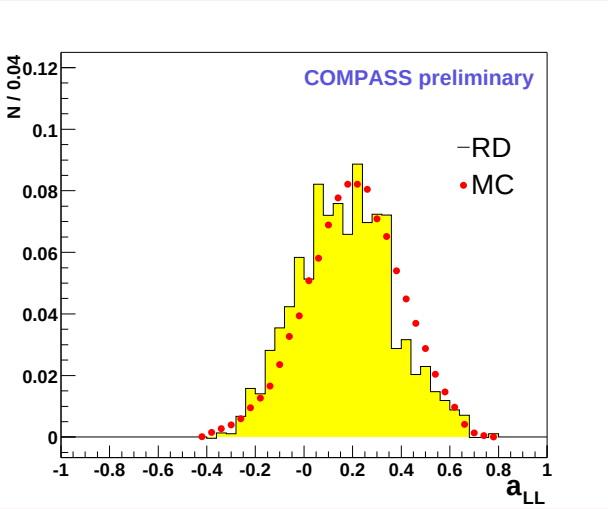
For $\Delta G \approx 2.5 \rightarrow$,
$\Delta\Sigma \approx 0.6$ and $\Delta s \approx 0$

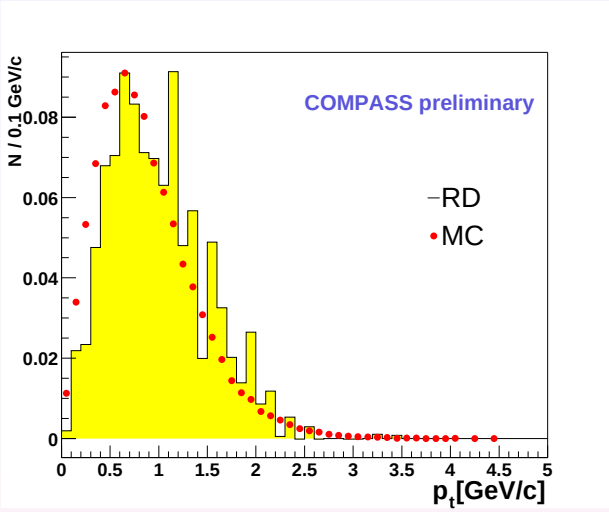
$\rightarrow$ Measure ΔG !!!

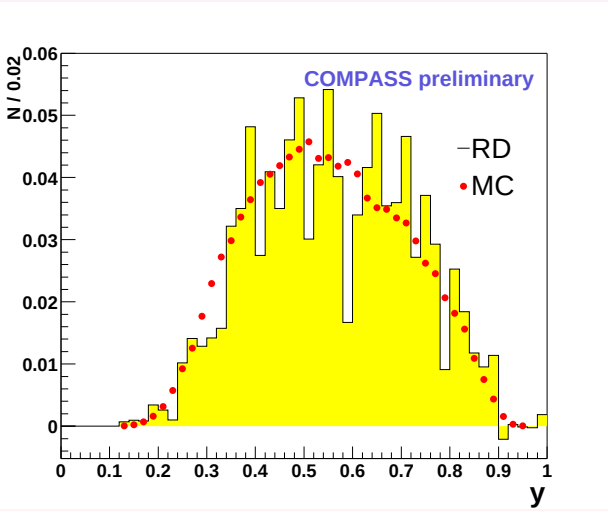
A large value of ΔG would give an explanation of the nucleon spin puzzle!

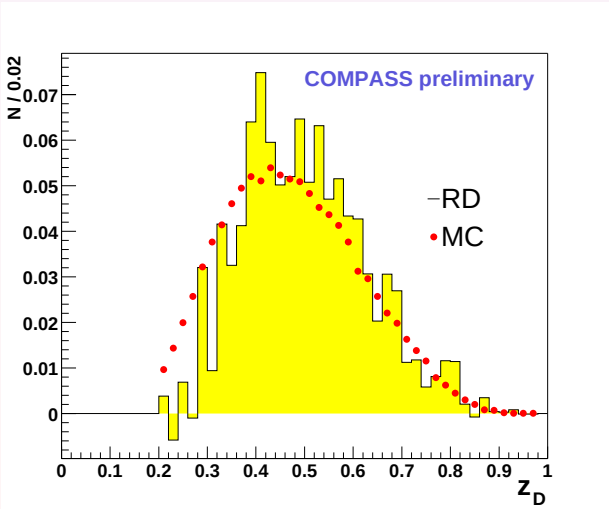
Open charm: Kinematic Distributions

Comparison data vs. MC

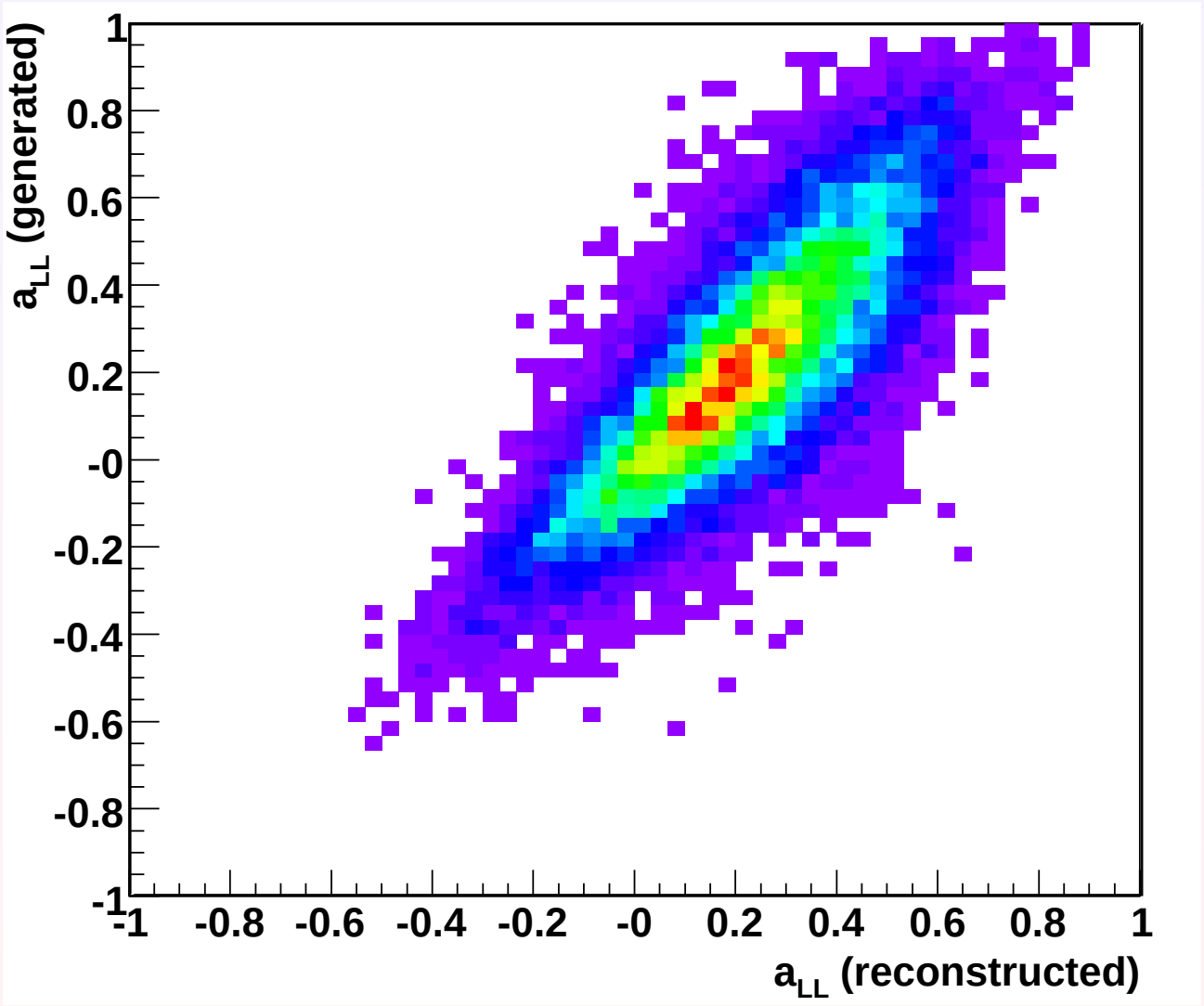




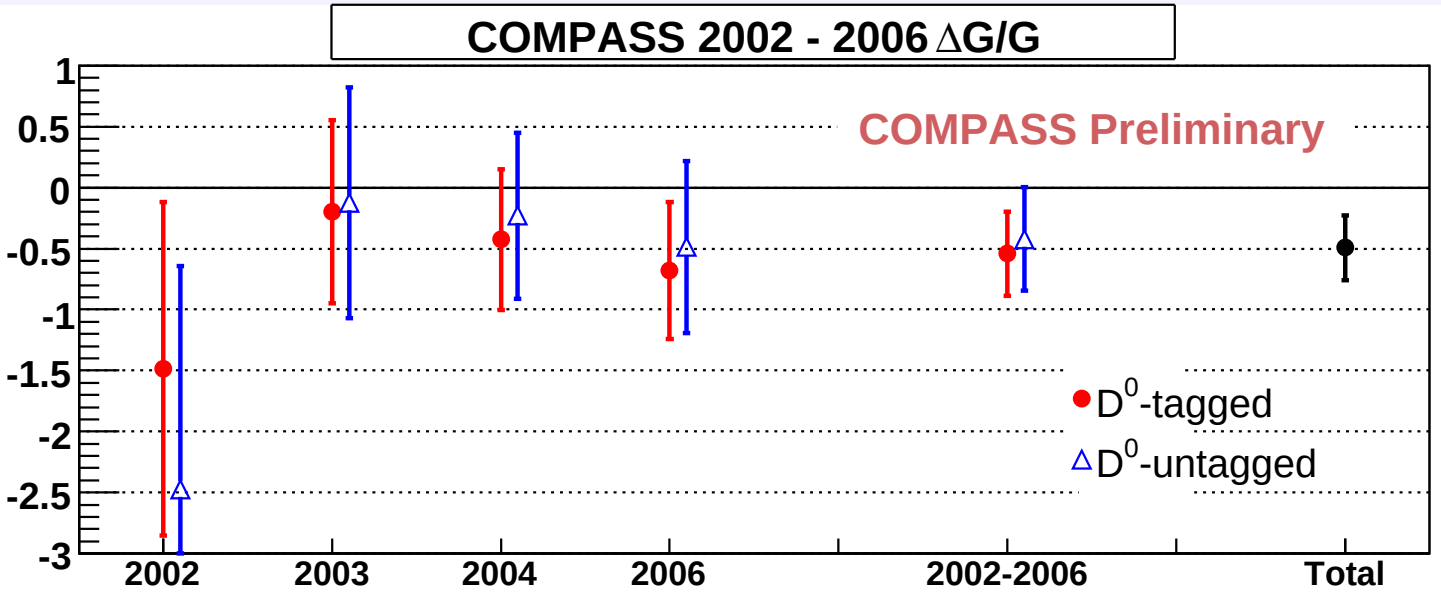




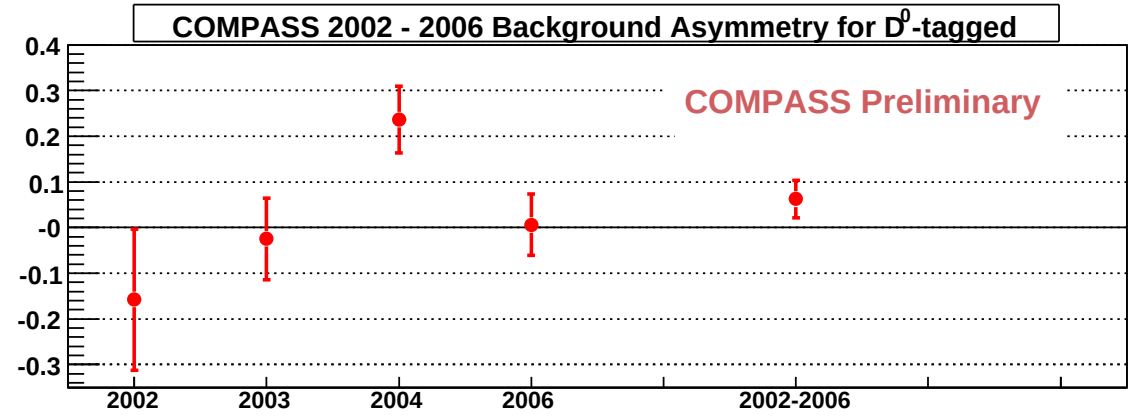
Determination of a_{LL}

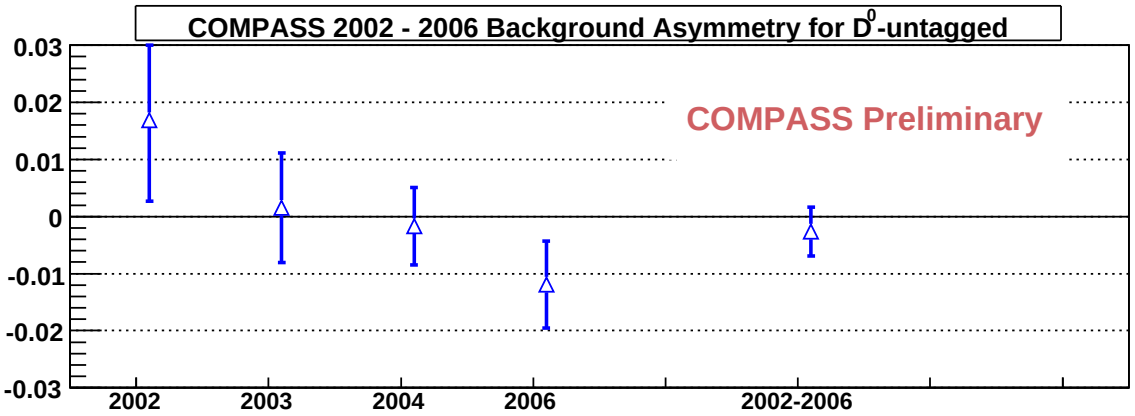


Result per year



Res


COMPASS 2002 - 2006 Background Asymmetry for D0-tagged
COMPASS Preliminary
0.4
0.3
0.2
0.1
-0
-0.1
-0.2
-0.3
2002
2003
2004
2006
2002-2006


COMPASS 2002 - 2006 Background Asymmetry for D0-untagged
COMPASS Preliminary
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
2002
2003
2004
2006
2002-2006

Neural Net ↔ MC