Recent COMPASS results on the gluon polarization

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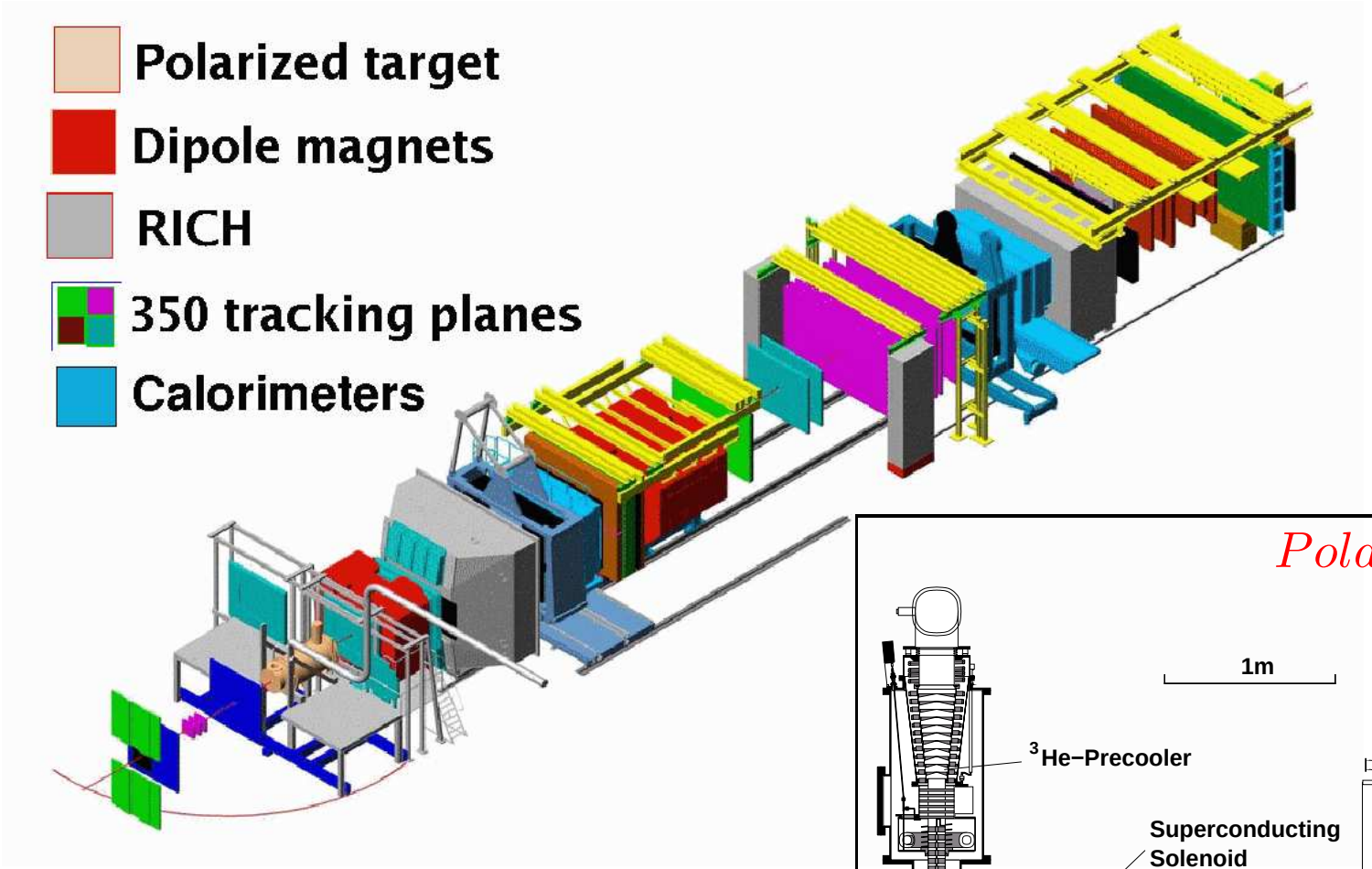
on behalf of the COMPASS Collaboration

13^{th} September 2008

Overview

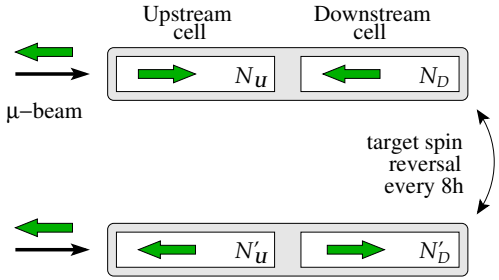
- The COMPASS experiment
- Gluon polarization
  - ⋆ Open charm analysis
  - ⋆ High p_T hadron pairs
- Results
- Summary and Conclusions

The COMPASS Experiment at CERN

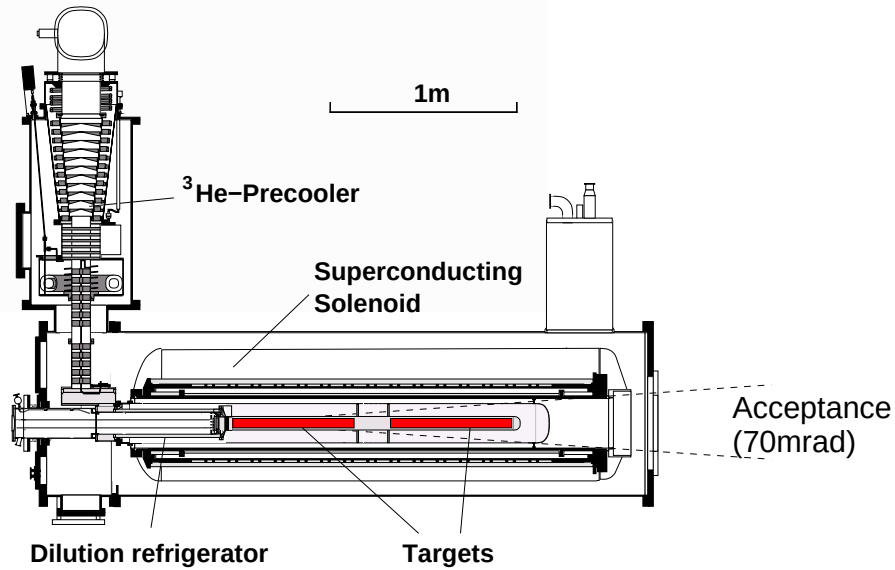


μ^+ beam @160 GeV

-80% polarization



Polarized target

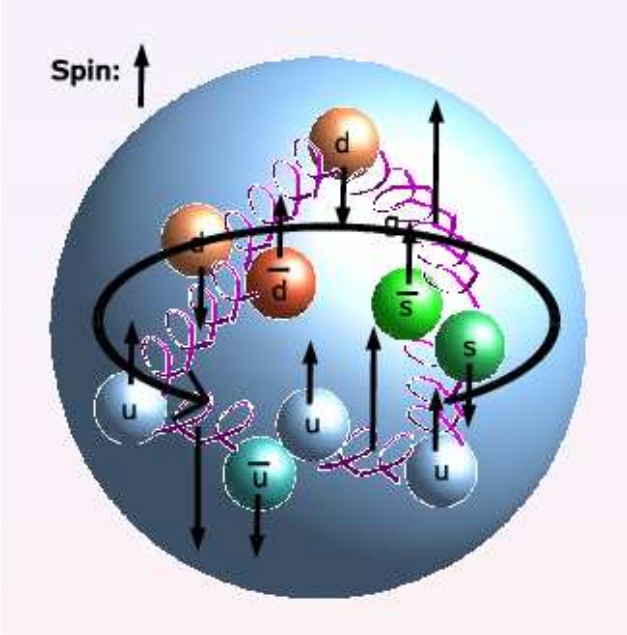


^6LiD target, $P_t \approx 50\%$, $f \approx 0.4$

The nucleon spin puzzle

$$\textbf{Nucleon spin: } \tfrac{1}{2} = \tfrac{1}{2}\,\Delta\Sigma + \Delta G + L_Z$$

quarks spin — gluons spin — orbital ang. mom.



- In the quark-parton model, including relativistic corrections, expect $\Delta\Sigma \approx 0.6$
- 1988: EMC measured the quarks contribution to the spin of the nucleon to be very small !
- Present world data:

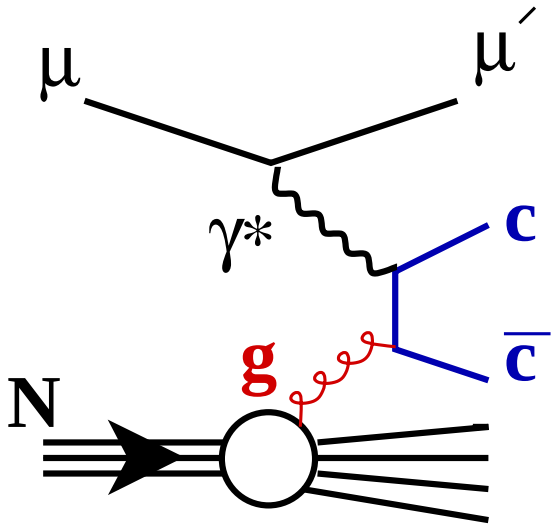
$$\Delta\Sigma = 0.30 \pm 0.01(\text{stat}) \pm 0.02(\text{evol})$$

↦ COMPASS, PLB 647 (2007) 8-17

Gluon polarization

The direct measurement of ΔG is of crucial importance for the understanding of the spin puzzle.

$\hookrightarrow$ Access it via the photon-gluon fusion process



PGF events are selected by analysing:

- Open Charm production

Gluon polarization

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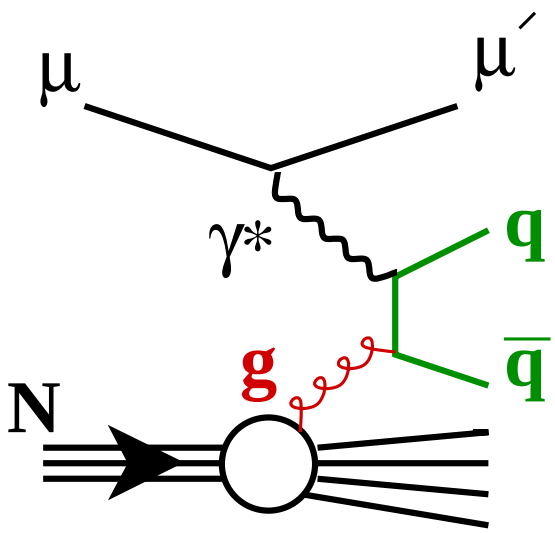
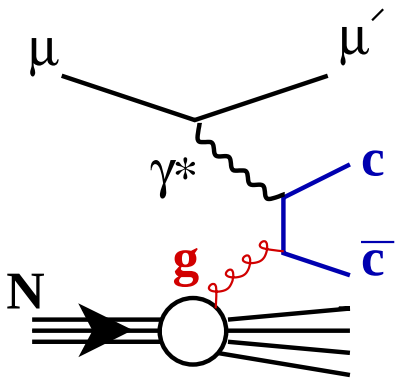


PGF events are selected by analysing:

- Open Charm production
- High p_T hadron pairs

Open charm analysis



Select events with D^o production

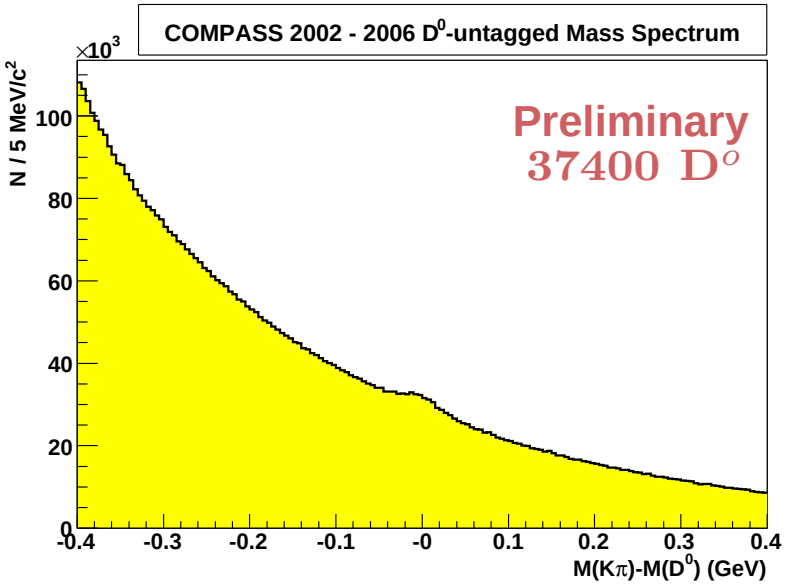
- Channels:
  - ★ $D^o \rightarrow K\pi$
  - ★ $D^* \rightarrow D^o\pi_{soft} \rightarrow K\pi\pi_{soft}$

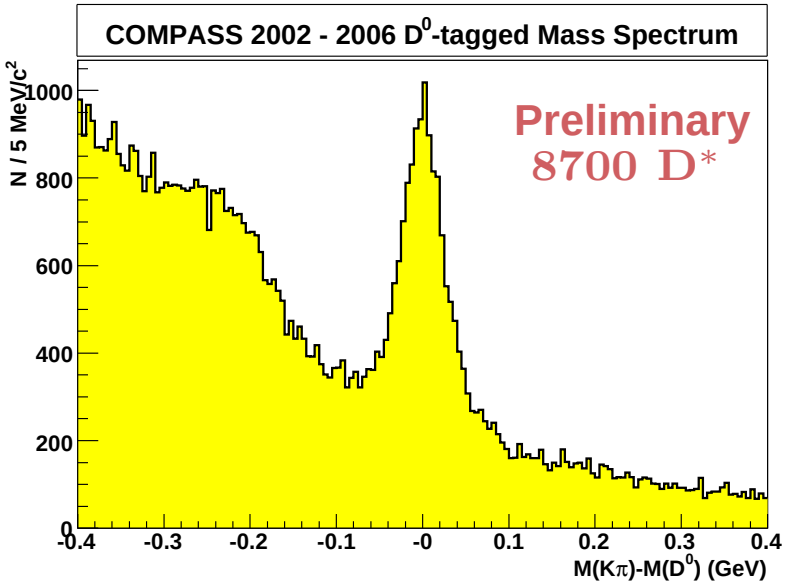
  BR($D \rightarrow K\pi$) $\approx 3.8\%$

- clean sample of PGF events (in LO approx.) ☺
- charm content of the nucleon is neglected
- Perturbative region ensured by m_c
- Weak dependence on the MC
- But: low statistics ☹

Open charm: statistics (2002 - 2006)

Mass spectra after kinematical cuts are applied:





Particle ID using RICH:

- π and K identified
- electrons rejected (avoid fake π_{slow})

$\Delta G/G$ from Open charm

The measured asymmetry can be decomposed as follows:

$$A_{exp} = \langle \frac{\Delta g}{g} \rangle P_t P_b a_{LL} f \frac{S}{S+B} + A_{bkg}$$

The experimental μ-N asymmetry is measured from the difference in events from the two oppositely polarized target cells:

$$A_{exp} = \frac{N^{\Rsh} - N^{\Lsh}}{N^{\Rsh} + N^{\Lsh}}$$

By solving a system of 8 equations with 7 unknowns (acceptances for each target cell in each spin configuration, $\langle \Delta g/g \rangle_x$ and A_{bkg}), one can extract simultaneously $\langle \Delta g/g \rangle$ and the background asymmetry, for D^o events (with or without D^* tagging).

Open charm: Method

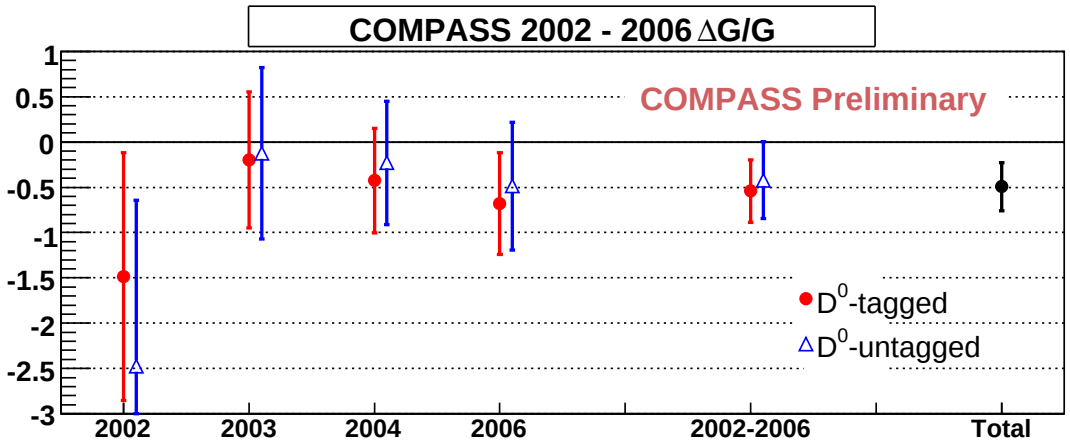
For optimal statistical gain, events are weighted by:

$$w = P_b \, f \, a_{LL} \, \frac{S}{S+B}$$

- a_{LL}: partonic asymmetry. Parametrized from MC in LO, with AROMA
- $\frac{S}{S+B}$ is parametrized as a function of relevant kinematical variables and RICH response, from fits to the mass spectra

Signal and background asymmetries are extracted simultaneously, from the fits to D^0 and D^* mass spectra.

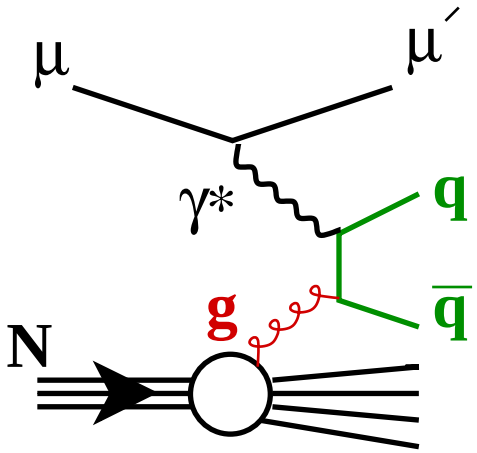
Open charm: Results



- $\Delta G/G = -0.49 \pm 0.27(stat) \pm 0.11(syst)$
  at $\langle x_g \rangle = 0.11\ ^{+0.11}_{-0.05}$ and $\langle \mu^2 \rangle = 13$ (GeV/c)^2.
- Background asymmetry is compatible with zero, within errors.
- Systematics (D^o-untagged/D^o-tagged):

source	$\delta(\Delta G/G)$	source	$\delta(\Delta G/G)$
false asymmetry	0.05/0.05	beam polar.	0.025
$S/(S+B)$	0.07/0.01	target polar.	0.025
a_{LL}	0.05/0.03	dilution factor	0.025
Total:	0.11/0.07		

High p_T hadrons analysis

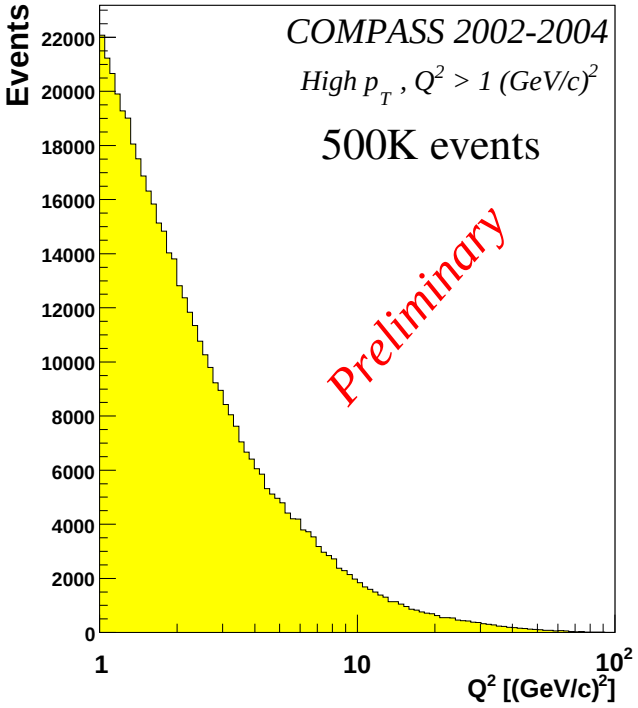


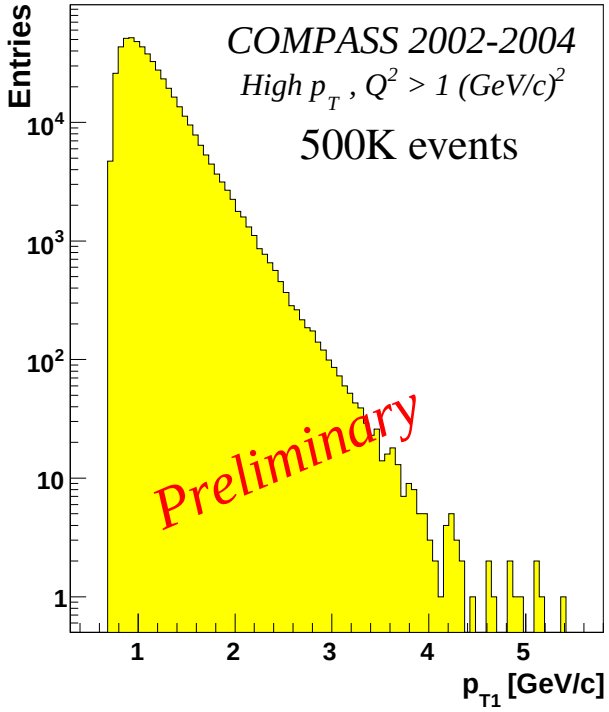
Select events with 2 hadrons in the final state

- Each hadron: $p_T > 0.7$ GeV/c
- Studied in different Q^2 regions:
  - ⋆ $Q^2 > 1$ (GeV/c)^2
    - ↪ this talk
  - ⋆ $Q^2 < 1$ (GeV/c)^2
    - ↪ Published (see PLB 633 (2006) 25-32)

- Large statistics available ☺
- Several background processes contributing ☹
- MC dependent ☹

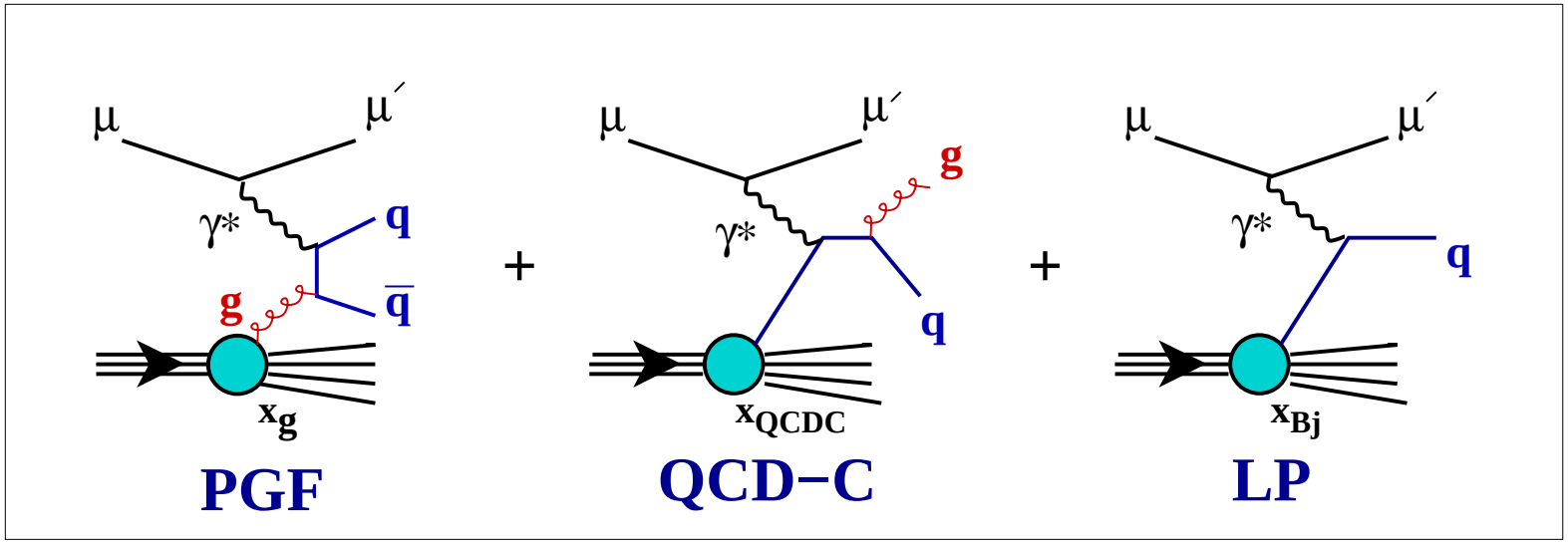
High p_T hadrons, $Q^2 > 1$ (GeV/c)^2 Statistics (2002 - 2004)





- $Q^2 > 1 (GeV/c)^2$ (cuts 90% of the statistics)
- p_{T1} and $p_{T2} > 0.7$ GeV/c

$\Delta G/G$ from high p_T hadron pairs



$$\frac{A_{exp}}{P_b P_t f} \approx R_{PGF} a_{LL}^{PGF} \frac{\Delta G}{G}(x_g) + R_{QCDC} a_{LL}^{QCDC} A_1^{LP}(x_{QCDC}) + R_{LP} a_{LL}^{LP} A_1^{LP}(x_{Bj})$$

with R_i: fraction of each process;

a_{LL}^i: the partonic asymmetry of each process;

$A_1^{LP} = \frac{\sum_i e_i^2 \Delta q_i}{\sum_i e_i^2 q_i}$: taken from inclusive asymmetry

Both R_i and a_{LL}^i are obtained from **MC**.

A_{exp} and A_1 obtained from **data**, with or without the high p_T hadrons cut.

f, P_t and P_b also from **data**.

$\Delta G/G$ from high p_T hadron pairs (II)

$$\frac{\Delta G}{G}(\langle x_g \rangle) = \frac{A_{LL}^{2h}(x_{Bj}) + A^{corr}}{\beta}$$

with $A_{LL}^{2h} = \frac{A_{exp}}{P_b P_t f}$

$$A^{corr} = A_1(x_{Bj})\beta_0 + A_1(x_{QCDC})\beta_1 + A_1(x'_{QCDC})\beta_2$$

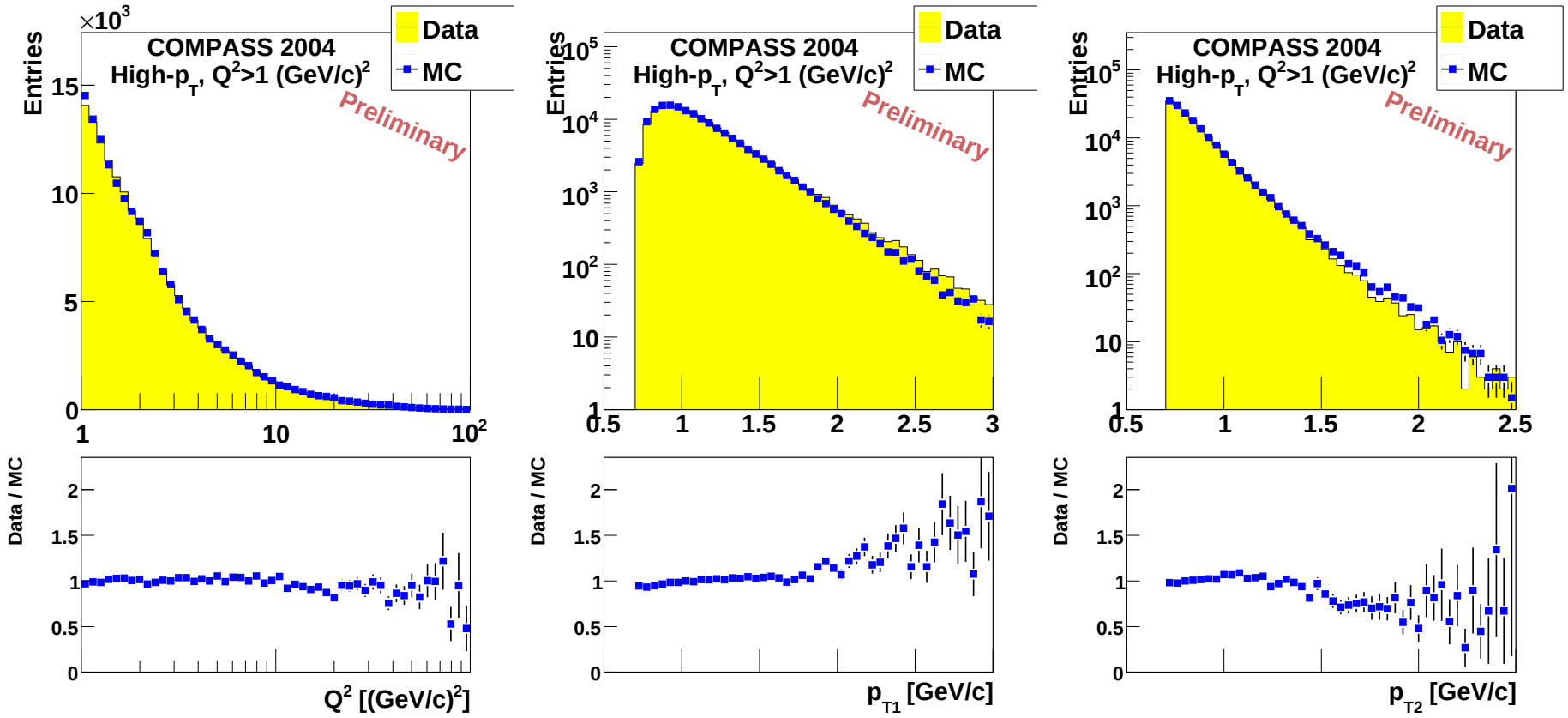
β factors depend on R_i and a_{LL}^i

- Events are weighted with $fDP_b\beta$ factor
- R_i, a_{LL}^i, x_g and x_{QCDC} are estimated using a **Neural Network** on a **MC** sample.

A good agreement between MC and Data is essential in this analysis.

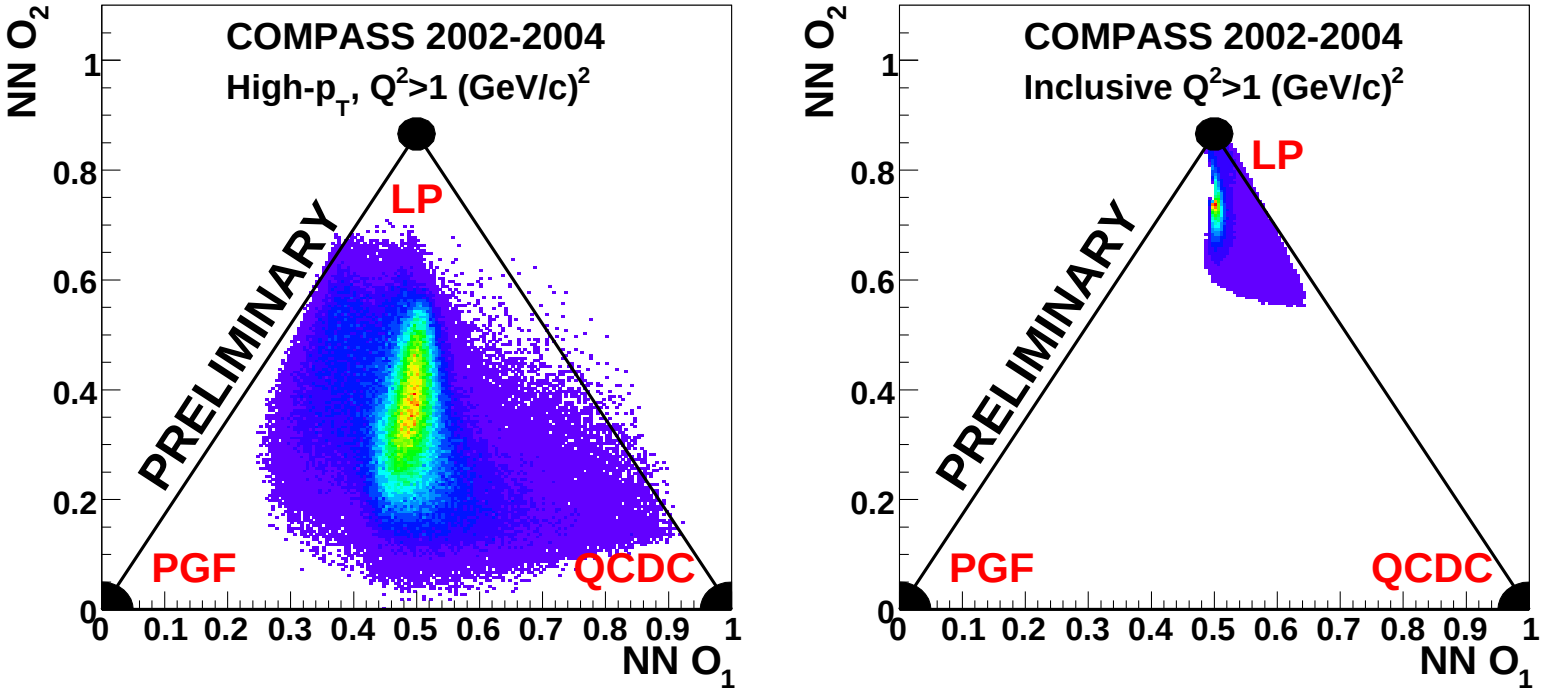
High p_T hadron pairs: MC

- MC: LEPTO (PDF set: MRST2004 LO; fragmentation: JETSET)
- Parton Shower ON: part of NLO corrections
- Tuning of JETSET fragmentation



High p_T hadron pairs: Fraction of each process

For each sample (high p_T or inclusive), the probability that each event be PGF, LP or QCDC is evaluated from a NN parametrizing R_i



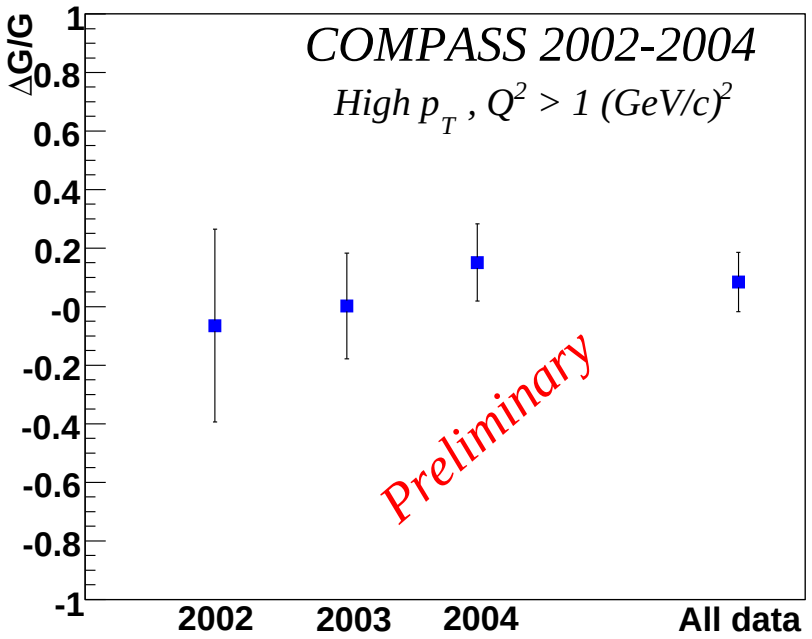
$$R_{PGF} = 1 - O_1 - \frac{1}{\sqrt{3}} O_2$$

$$R_{QCDC} = O_1 - \frac{1}{\sqrt{3}} O_2$$

$$R_{LP} = \frac{2}{\sqrt{3}} O_2$$

R's sum up to unity

High p_T hadron pairs: Results



- Major systematics:

source	$\delta(\Delta G/G)$
NN	0.006
MC	0.040
f, P_b, P_t	0.006
false asymmetry	0.011
A_1	0.008
formula	0.013
Total	0.045

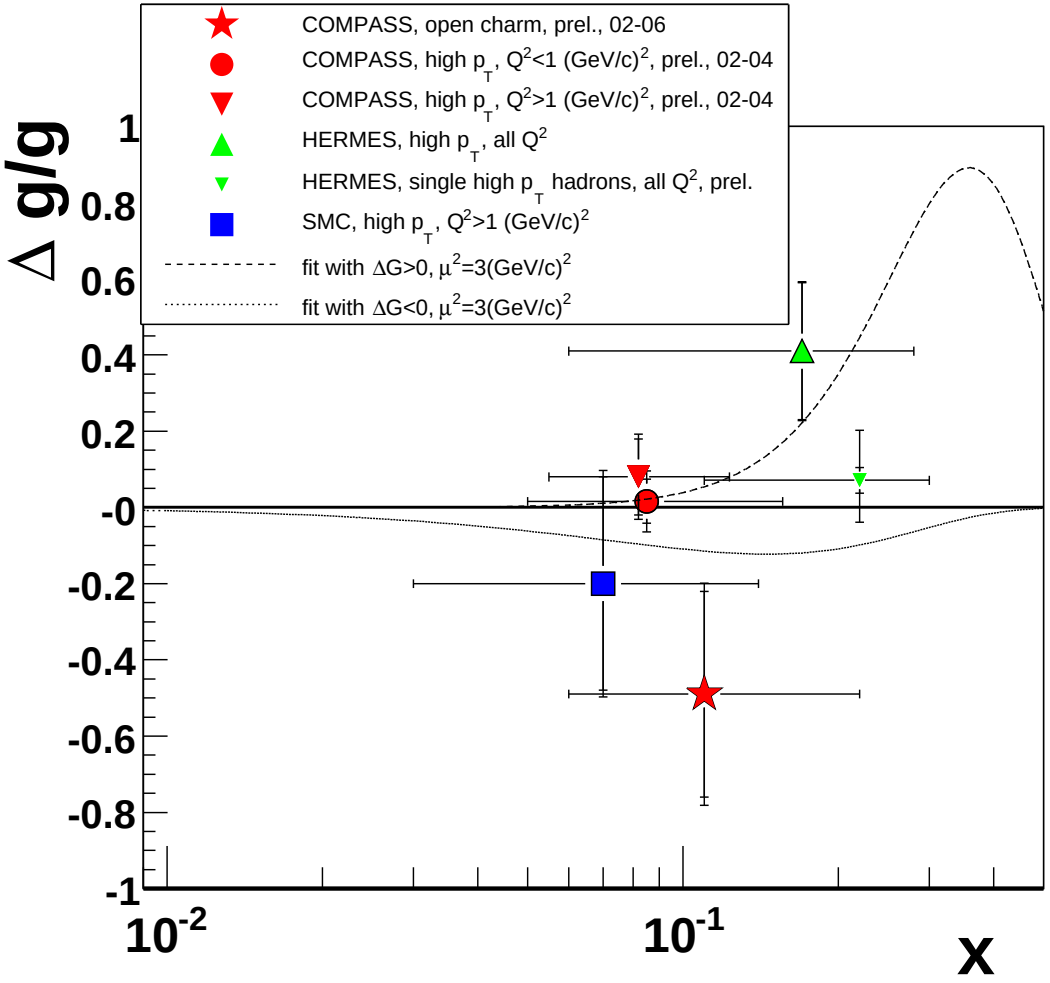
- $\Delta G/G = 0.08 \pm 0.10(stat) \pm 0.05(syst)$

at $x_g^{av} = 0.082\ ^{+0.041}_{-0.027}$ and $\langle \mu^2 \rangle = 3$ (GeV/c)^2.

For $Q^2 < 1$ (GeV/c)^2, results were published and presented in conferences:

$\Delta G/G = 0.016 \pm 0.058(stat) \pm 0.054(syst)$ $\rightarrow$ 2002-2004 Preliminary

$\Delta G/G$ measurements



- COMPASS results are direct measurements of $\Delta G/G$
- $\Delta G/G$ is compatible with zero at $x_g \approx 0.1$

Summary and Conclusions

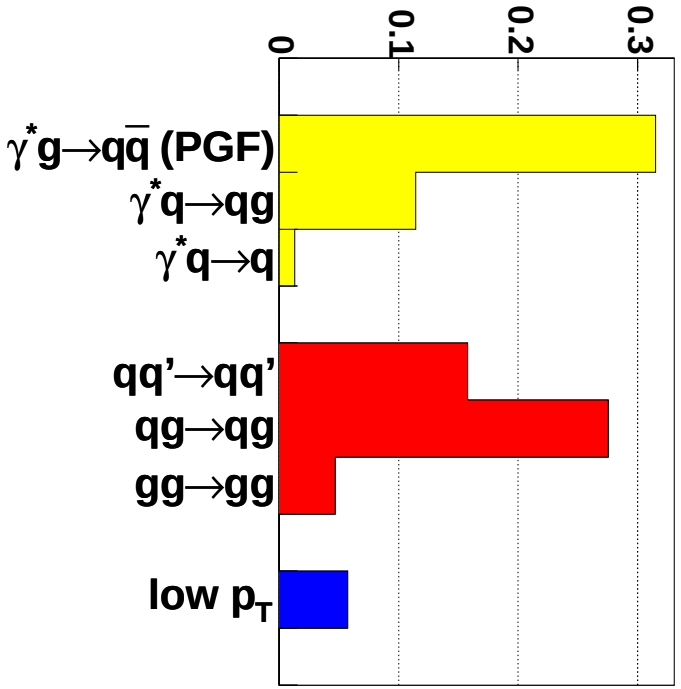
- Recent analyses were presented, which optimize the statistical significance of the data
- Results from COMPASS indicate that $\Delta G/G$ has a small value, compatible with zero, at $x_g \approx 0.1$

- COMPASS has still more data to analyse (2007 in the case of open charm analysis, 2006 & 2007 for high p_T hadron pairs)
- Possible improvements to the analyses are on-going:
  - ⋆ Open charm: improve tagging method; and do NLO analysis
  - ⋆ High p_T hadrons: loosen p_T cuts; and 1-hadron analysis

SPARE: High p_T hadron pairs at $Q^2 < 1$ (GeV/c)^2

Quasi-real photo-production of high p_T hadron pairs

- The scale is given by the p_T of the hadrons, with an additional cut $\sum p_{T\ 1,2}^2 > 2.5$ (GeV/c)^2
- More statistics available ☺
- More background processes contributing: resolved photon ☹
- More MC dependent ☹



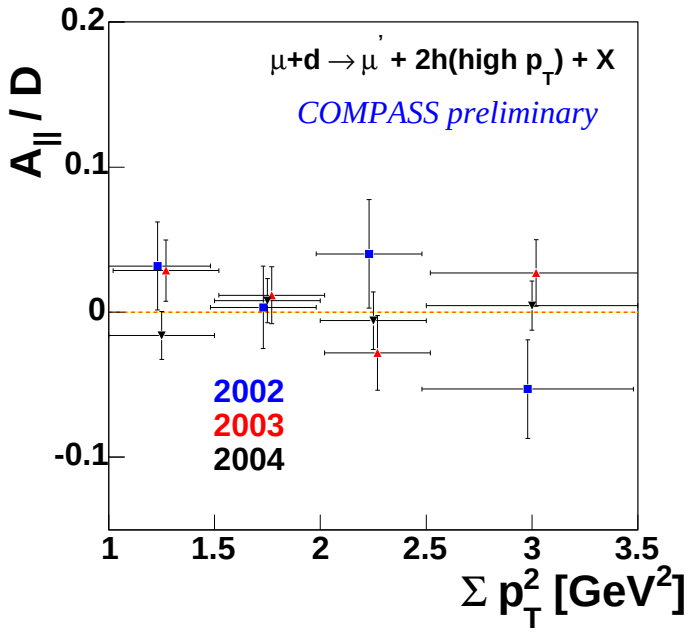
The PYTHIA generator is used to estimate the fractions R_i and a_{LL}.

$R_{PGF} \approx 30\%$

$R_{res.phot.} \approx 50\%$

SPARE:

High p_T hadron pairs at $Q^2 < 1$ (GeV/c)^2: Results



$\sum p_T^2 > 2.5$ (GeV/c)^2 chosen

From LO analysis:

$$\Delta G/G = 0.024 \pm 0.089(stat) \pm 0.057(syst)$$

at $\langle x_g \rangle = 0.095\ ^{+0.08}_{-0.04}$ and $\langle \mu^2 \rangle = 3$ (GeV/c)^2

$\hookrightarrow$ 2002-2003

Published: PLB 633 (2006) 25-32.

$$\Delta G/G = 0.016 \pm 0.058(stat) \pm 0.036(syst)$$

at $\langle x_g \rangle = 0.085\ ^{+0.07}_{-0.04}$ and $\langle \mu^2 \rangle = 3$ (GeV/c)^2

$\hookrightarrow$ 2002-2004 PRELIMINARY