ΔG from COMPASS

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on behalf of the COMPASS Collaboration

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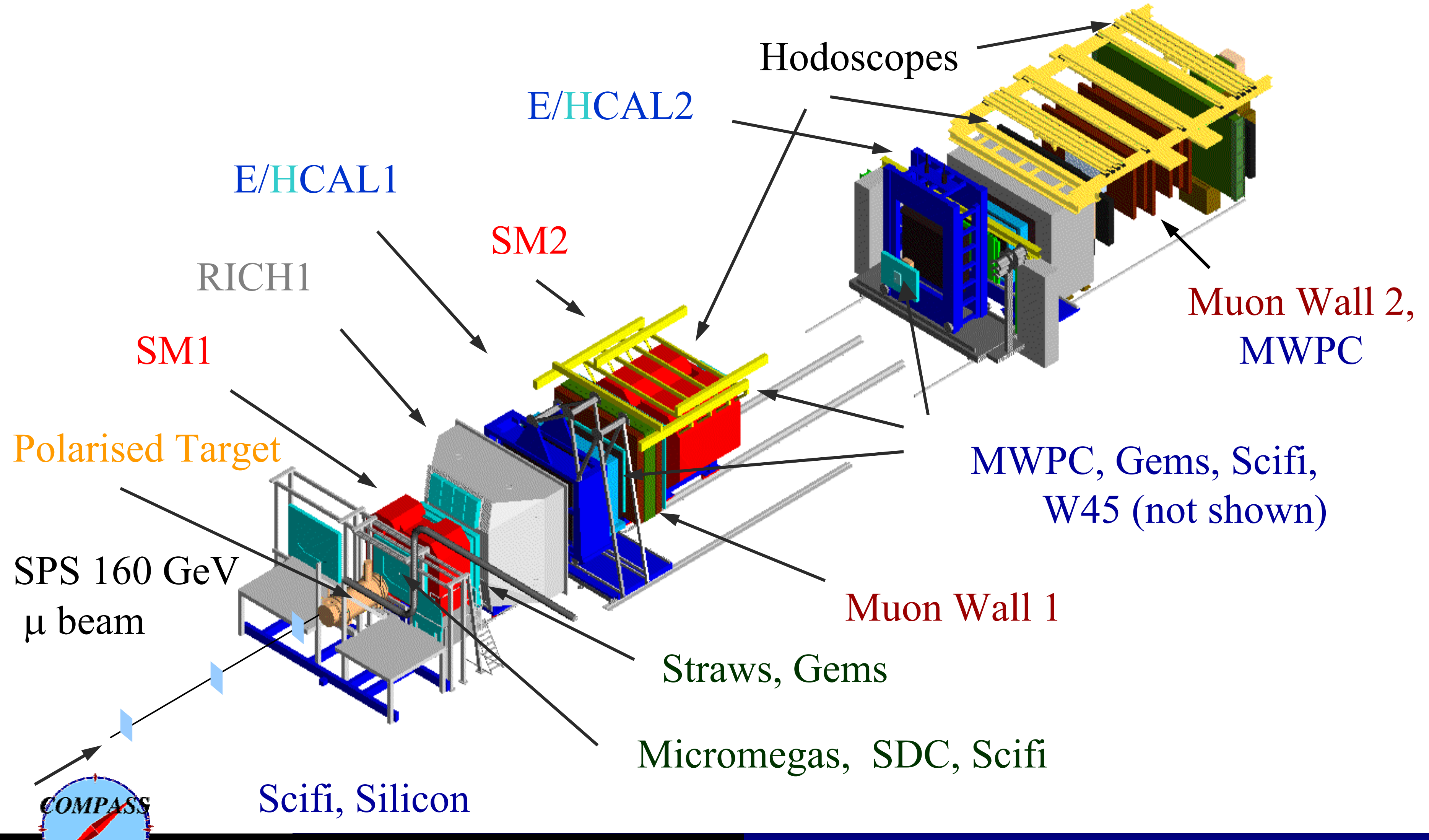
Tsukuba

- longitudinally polarised muon beam
- longitudinally or transversely polarised deuteron (^{6}LiD) target
- momentum and calorimetry measurement
- particle identification

luminosity:	~5 · 10^{32} cm^{-2} s^{-1}
beam intensity:	2·10^{8} μ+/spill (4.8s/16.2s)
beam momentum:	160 GeV/c
target polarization:	*~50%*

THE COMPASS SPECTROMETER



Content

- Motivation and Nucleon spin decomposition.
- Three methods of accessing $\frac{\Delta G}{G}$ in Compass.
- Open charm channel method and results.
- High p_T hadron pairs method:
  - Results for events with low Q^2.
  - Results for events with $Q^2 > 1$ GeV^2.
- Conclusions.

Nucleon Spin decomposition

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

- A very small fraction of the proton spin is carried by the spin of the quarks - put the naive but well-accepted quark model into serious questioning!
  (EMC (1988): $a_0 = \Delta\Sigma = 12 \pm 9 \pm 14\%$ while $\approx 60\%$ expected, confirmed by SMC, SLAC and Hermes : $\Delta\Sigma = 20 - 30\%$)

- The possible role of axial anomaly:
  measured quantity $a_0 = \Delta\Sigma - (3\,\alpha_S/2\pi)\,\Delta G$

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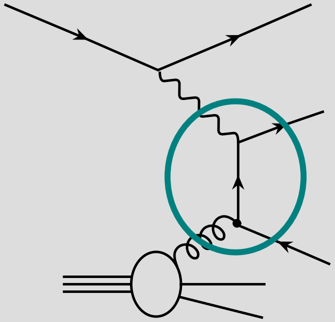
  measured quantity $a_0 = \Delta\Sigma - (3\,\alpha_S/2\pi)\,\Delta G$
  warning: orbital angular momentum – anomaly cancelled (X.Ji)

Direct measurements of ΔG/G

$$A_{||} = R_{PGF} a^{LL}_{PGF} \frac{\Delta G}{G} + A_{Bkg}$$

gluons



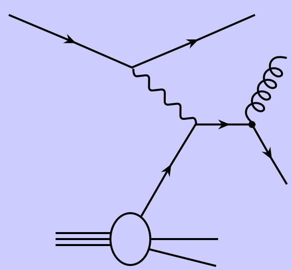
- Open charm „golden channel”
  - ☺ no background asymmetry, less MC dependent.
  - ☹ small statistics, NLO corrections can be important
- 2 high p_T hadrons ($p_T > 0.7$, then selection on Σp_T^2)
  - ☺ Large statistics
  - ☹ physical background: „model” (MC) dependent, requires very good description of data by MC.

Direct measurements of ΔG/G

2 high p_T hadrons:

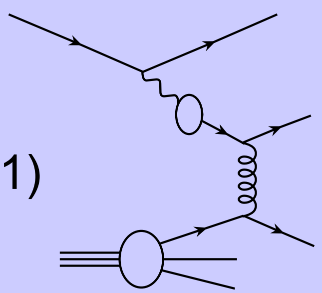
- Low Q^2 analysis ($Q^2<1$): perturbative scale fixed by p_T, complicated physical background e.g. resolved γ,low p_T
- High Q^2 analysis ($Q^2>1$): scale Q^2 ,physical background better controlled in the frame of pQCD.

Physical background:



QCD-Compton

resolved γ ($Q^2<1$)



Direct measurements of $\Delta G/G$

Due to limitations of every methods - high p_T hadron pairs methods are complementary to one another and complementary with the method using selection of open charm production!

$\Delta G/G$ from open charm channel

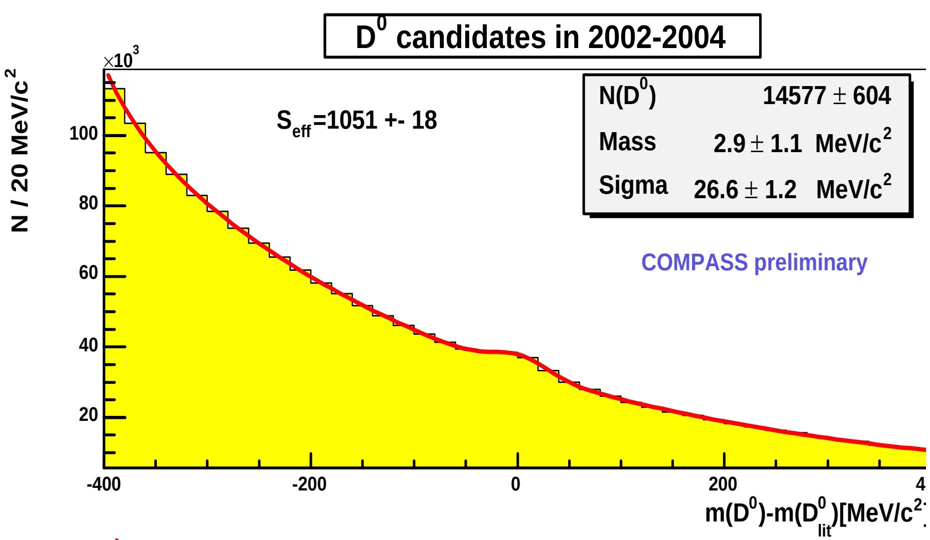
ΔG/G from open charm channel

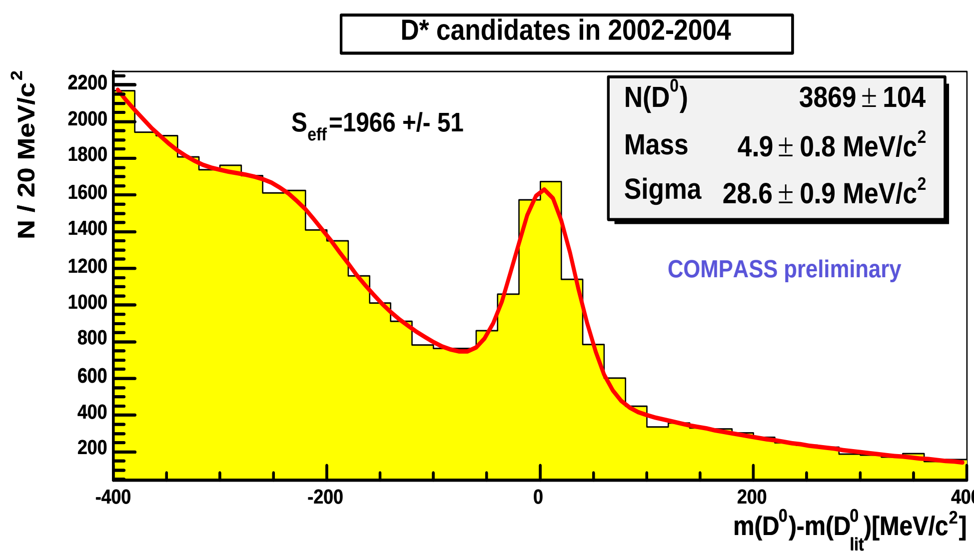
$$A_{LL}/D = \frac{S}{S+B}\,\tilde{a}_{LL}\,\frac{\Delta G}{G}(x_g)$$

Scale: <Q^2> ≈ 13 GeV^2
~4* m_c^2

$D^0 + \pi \rightarrow K + \pi$ (untagged)

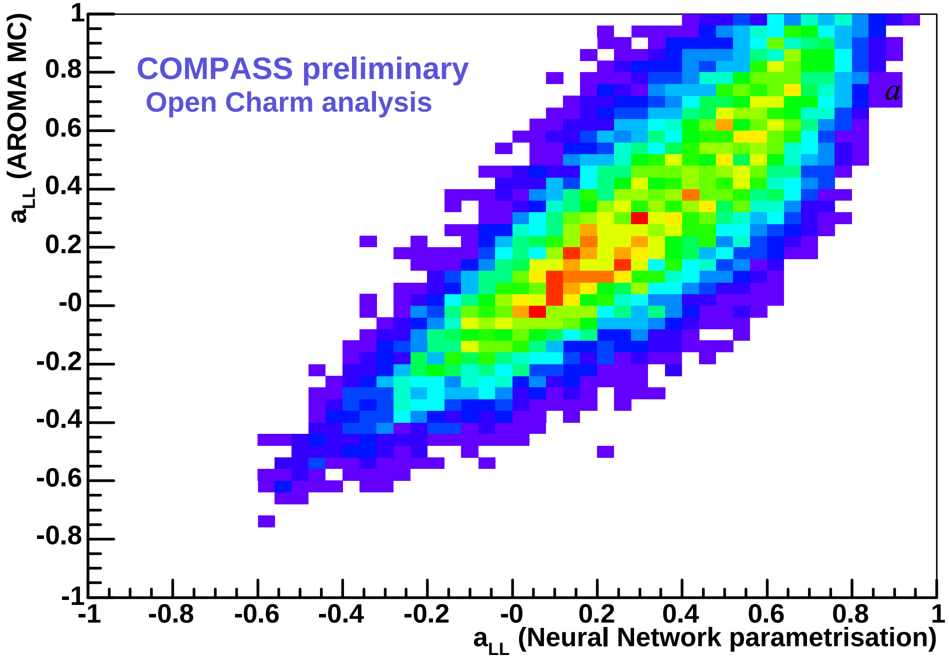
$D^* \rightarrow D^0 + \pi \rightarrow K + \pi + \pi$





ΔG/G from open charm channel

$$A_{LL}/D = \frac{S}{S+B}\,\tilde{a}_{LL}\,\frac{\Delta G}{G}(x_g)$$

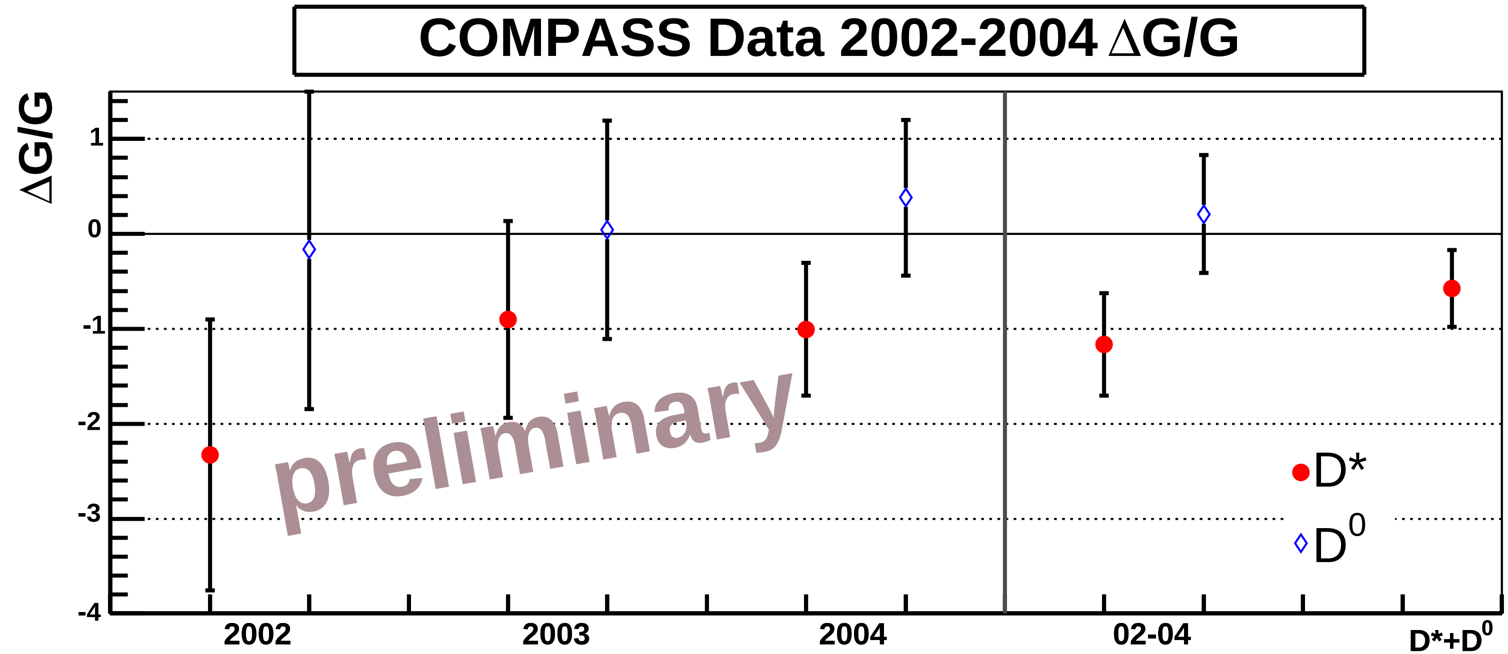


$\tilde{a}_{LL}$ – calculated with help of MC and parametrized by measured quantities (Neural Network used)

ΔG/G from open charm channel

D^0 + D* result 2002 – 2004: $\frac{\Delta G}{G}$ = -0.57 ± 0.41(stat.) @ $x_g \approx 0.15$, scale ≈13 GeV²

The studies on the systematical uncertainty are ongoing



$\Delta G/G$ from 2 high p_T hadrons

$\Delta G/G$ from 2 high p_T hadrons (low Q^2)

Low Q^2: $Q^2 > 1$ GeV^2

$$A_{LL}/D = R_{pgf}\,\Delta G/G\; a_{LL}^{pgf}$$

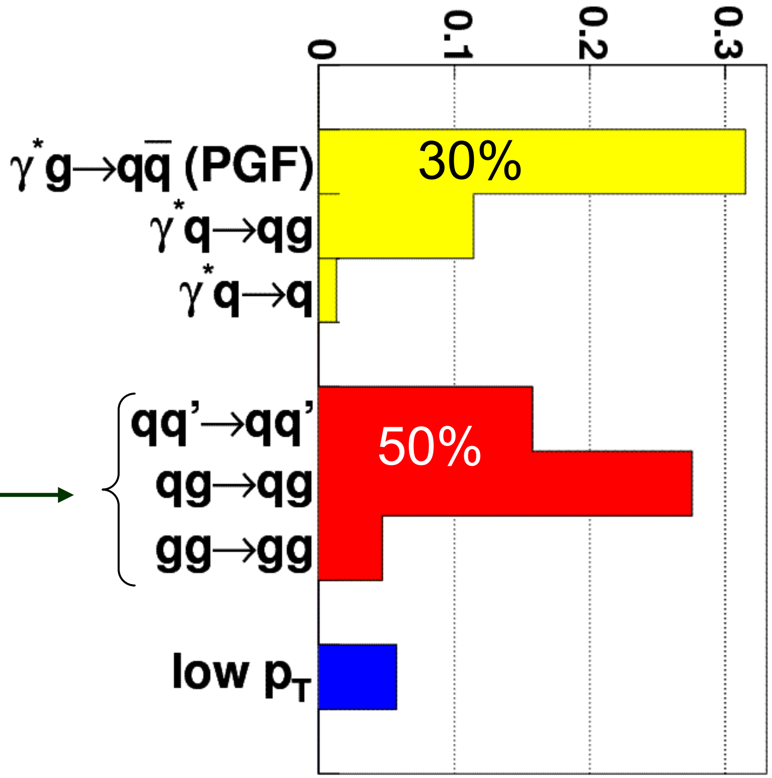
$$+ R_{qcdc}\,\Delta q/q\; a_{LL}^{qcdc}$$

Resolved γ

$$+ R_{qq}\,\Delta q/q\; a_{LL}^{gq}\,(\Delta G/G)^{\gamma}$$

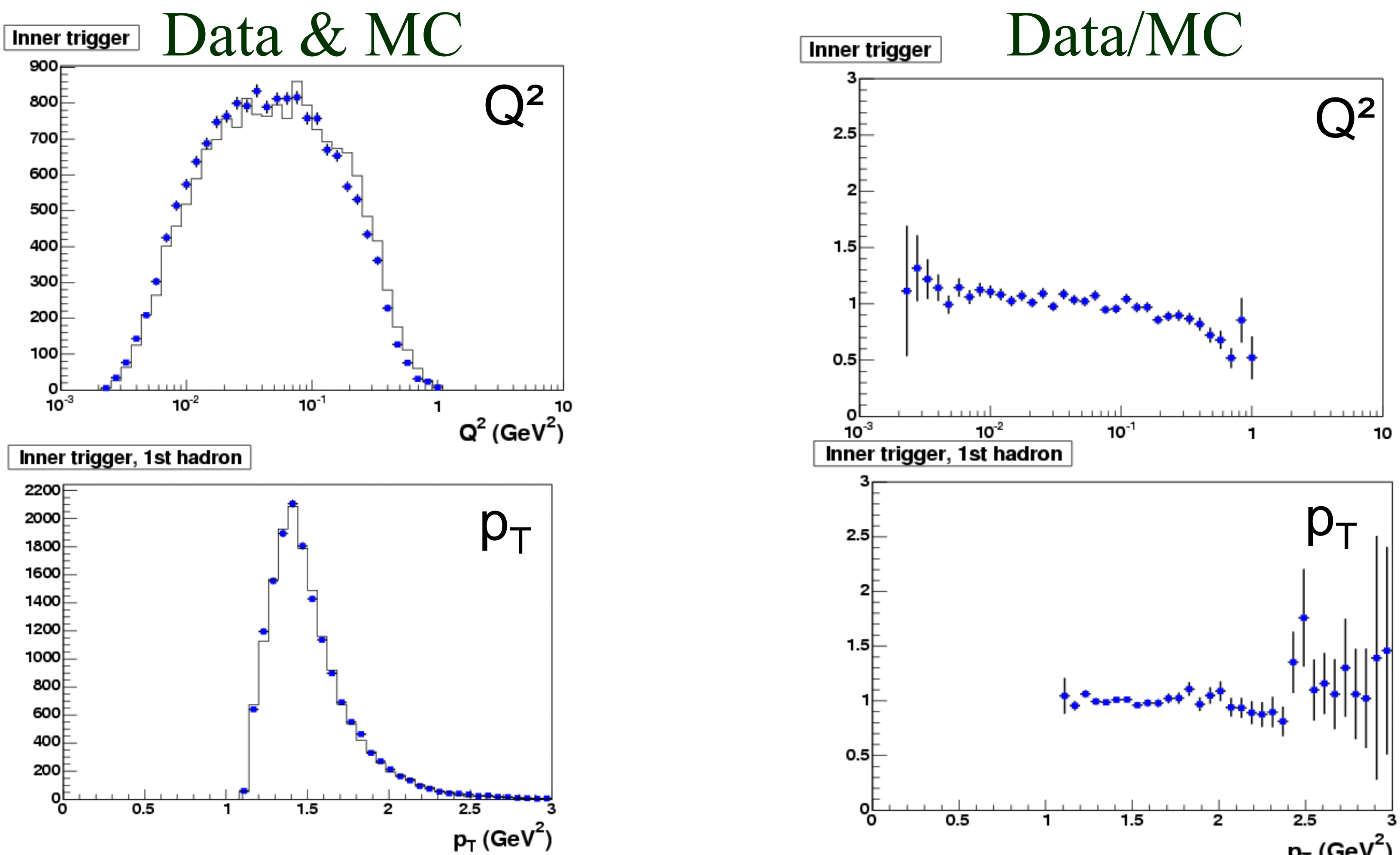
$$+ R_{qg}\,\Delta G/G\; a_{LL}^{qg}\,(\Delta q/q)^{\gamma}$$

$$+ \ldots$$



MC event generator *PYTHIA* is used for low Q^2 analysis

ΔG/G from 2 high p_T hadrons (low Q^2)



Example of good description of the data by the simulation

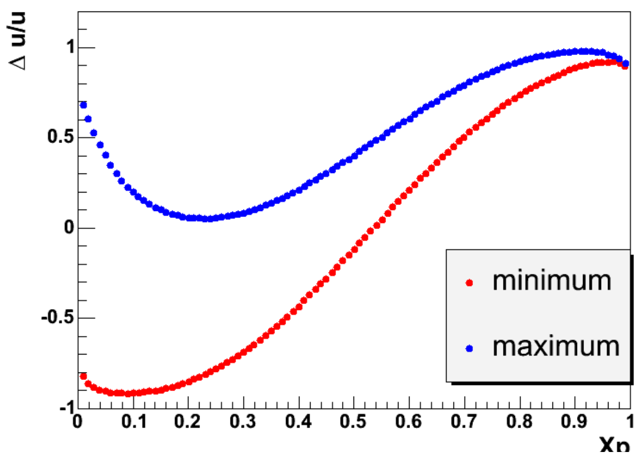
$\Delta G/G$ from 2 high p_T hadrons (low Q^2)

Problem: polarized PDF's of virtual photons not measured!

$\Delta q^{\gamma,pert}(x_p,\mu^2)$ calculable

$$-q^{\gamma,npert}(x_p,\mu_0^2) < \Delta q^{\gamma,npert}(x_p,\mu_0^2) < q^{\gamma,npert}(x_p,\mu_0^2)$$

measured

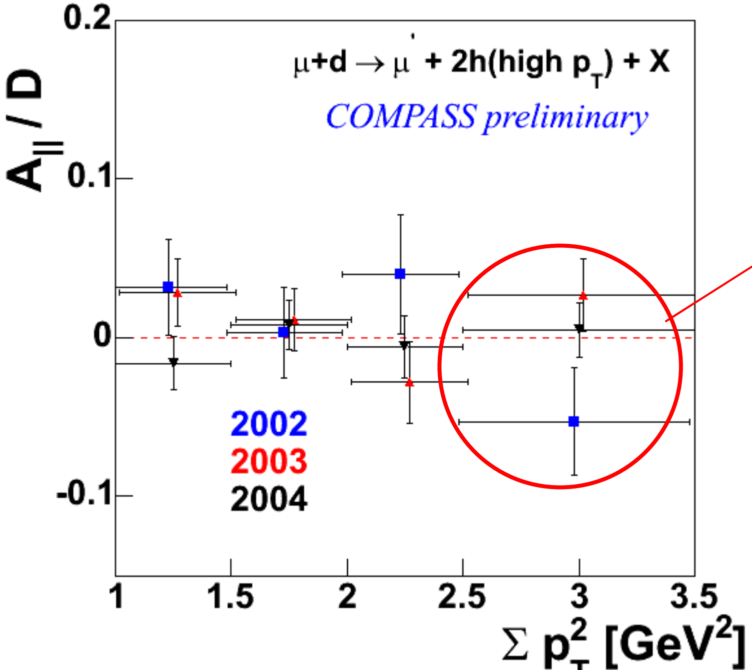


$\Rightarrow$ Allows us to obtain a range for $(\Delta q/q)^\gamma$ and $(\Delta G/G)^\gamma$

$\rightarrow$ Adds a limited uncertainty to the estimation of $(\Delta G/G)(x_g)$

Resolved photon asymmetry

$\Delta G/G$ from 2 high p_T hadrons (low Q^2)



Values used for extraction of $\Delta G/G$

data	$(\Delta G/G)(x_g)$	stat	exp.syst	MC.syst	γ
02-03	0.024	0.089	0.014	0.052	0.018
02-04	0.016	0.058	0.014	0.052	0.013

$$@\, x_g = 0.085^{+0.071}_{-0.035}$$

2002-2003 published:PLB **633** (2006) 25-32

$\Delta G/G$ from 2 high p_T hadrons ($Q^2 > 1$)

- Statistics smaller than in low Q^2 analysis (10%)
- Background better controlled – pQCD (QCD-C, LP)
- *LEPTO* MC generator has been used for data description (tunning similar to SMC)
- $\Sigma p_T^2 > 2.5$ GeV^2 used.

2002-2003 data result:

$$\frac{\Delta G}{G} = 0.06 \pm 0.31(\text{stat.}) \pm 0.06 \;@\; x_g = 0.13 \pm 0.08$$

$\Delta G/G$ from 2 high p_T hadrons ($Q^2 > 1$)

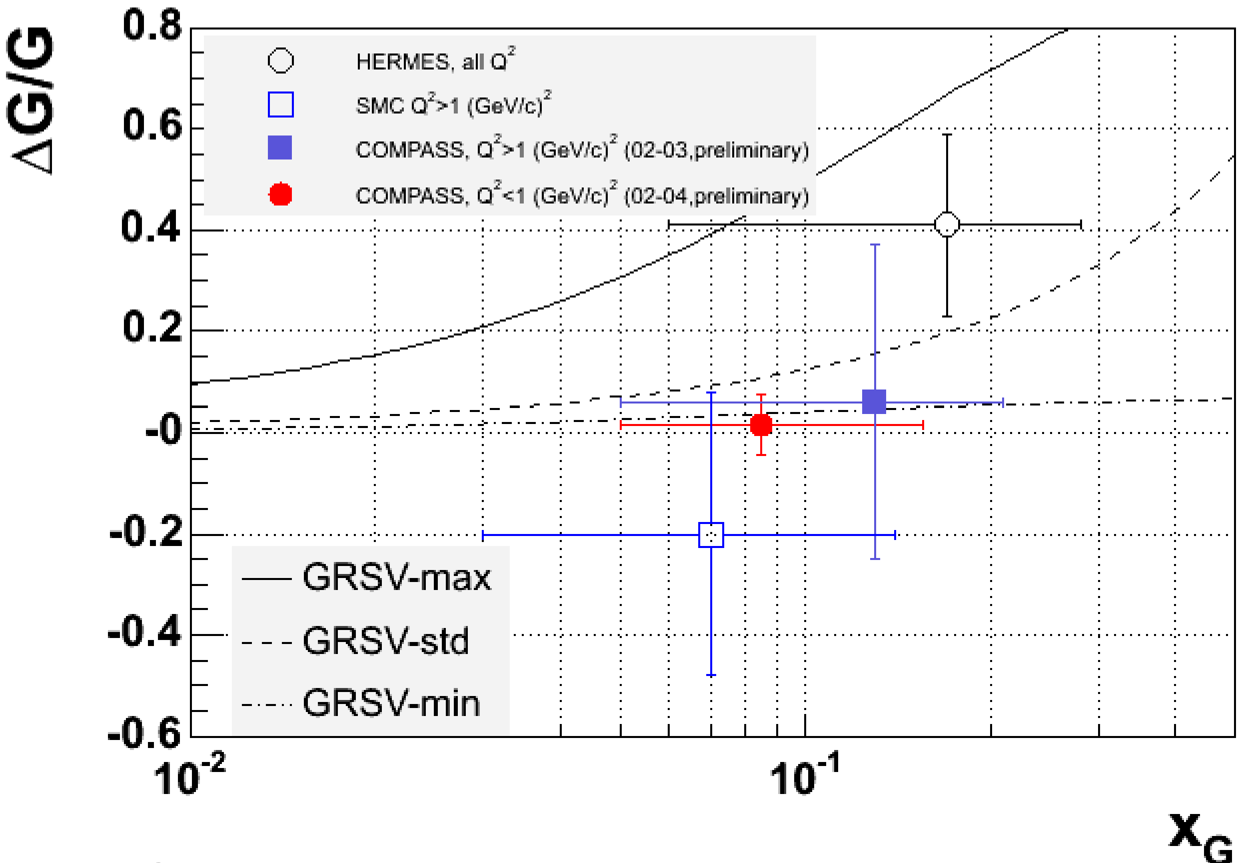
- Analysis is ongoing; 2002-2004 results expected soon
- Scale is determined by Q^2 and – in contrast to low Q^2 analysis – the cut $\Sigma p_T^2 > 2.5$ GeV^2 can be released to smaller value to optimize „working point"

(question: higher fraction R_{PGF} and small statistics or lower fraction and higher statistics?)

- Neural Network is tested to improve selection of PGF subprocess and optimize „working point".
The significant improvement is expected.

Results for ΔG/G - summary

$$\int \Delta G(x) = 2.5$$



$$\int \Delta G(x) = 0.62$$

$$\int \Delta G(x) = 0.16$$

Only statistical errors plotted

Results for ΔG/G - summary

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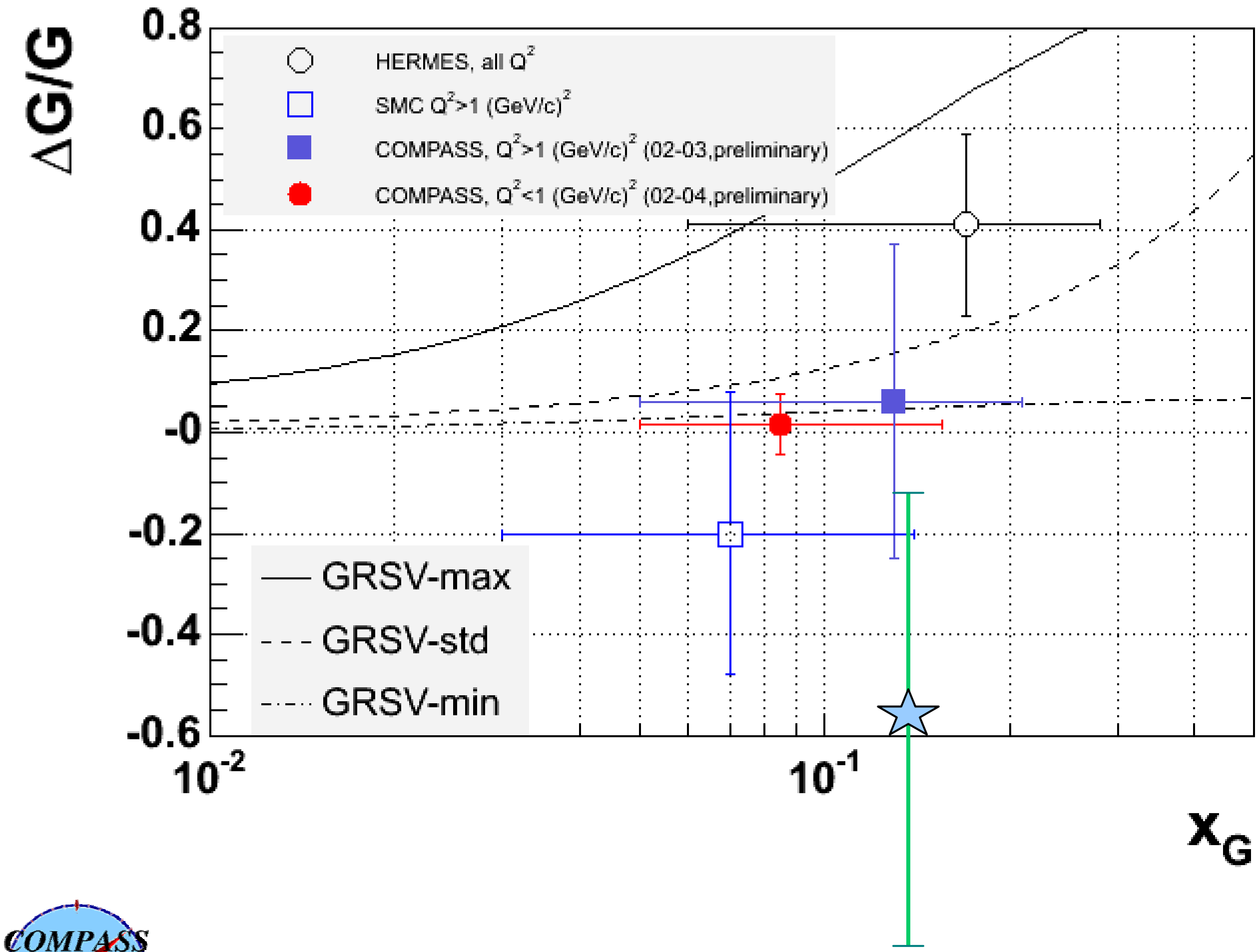

$$\int \Delta G(x) = 0.62$$

$$\int \Delta G(x) = 0.16$$

☆ Open charm

Outlook

- More results soon available with 2004 data for $Q^2 > 1$ GeV^2 high p_T events

- For the future:
  - Optimization of event selection with a neural network
  - Bins in x_g (requires improvement of x_g reconstruction)
  - NLO in open charm analysis

- 2006 data with new COMPASS magnet (larger x_g)

Summary

- New measurements of $\Delta G/G$ have been presented.
- Small ΔG is preferred or $\Delta G(x_g)$ has a node around 0.1.
- Ellis-Jaffe sum rule seems to be violated if large ΔG is excluded (axial anomaly).

- $\Delta G \approx 0.4$ not excluded and scenario when L is small still possible.
- $\Delta G \approx 0$ indicates the important role of angular orbital momentum in nucleon spin decomposition described in the frame of parton model and pQCD.