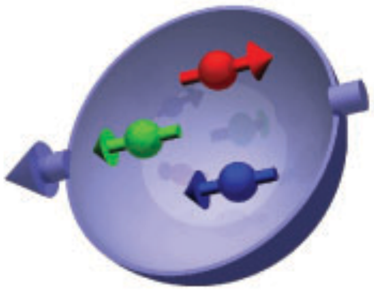
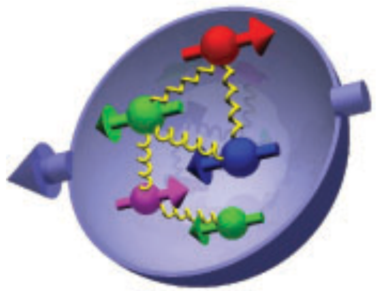
$\Delta G/G$ from high p_T hadron pairs at $Q^2 > 1$ (GeV/c)^2

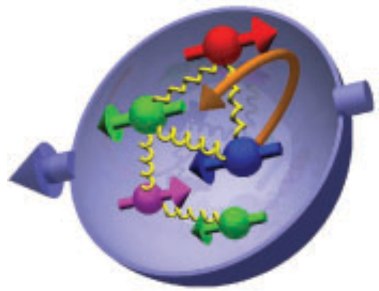
Contributions to the nucleon spin



CQM (EJ):
$\Delta\Sigma \sim 0.6$



E&SMC,SLAC,HERMES
CLAS,COMPASS g_1:
$\Delta\Sigma \sim 0.3$



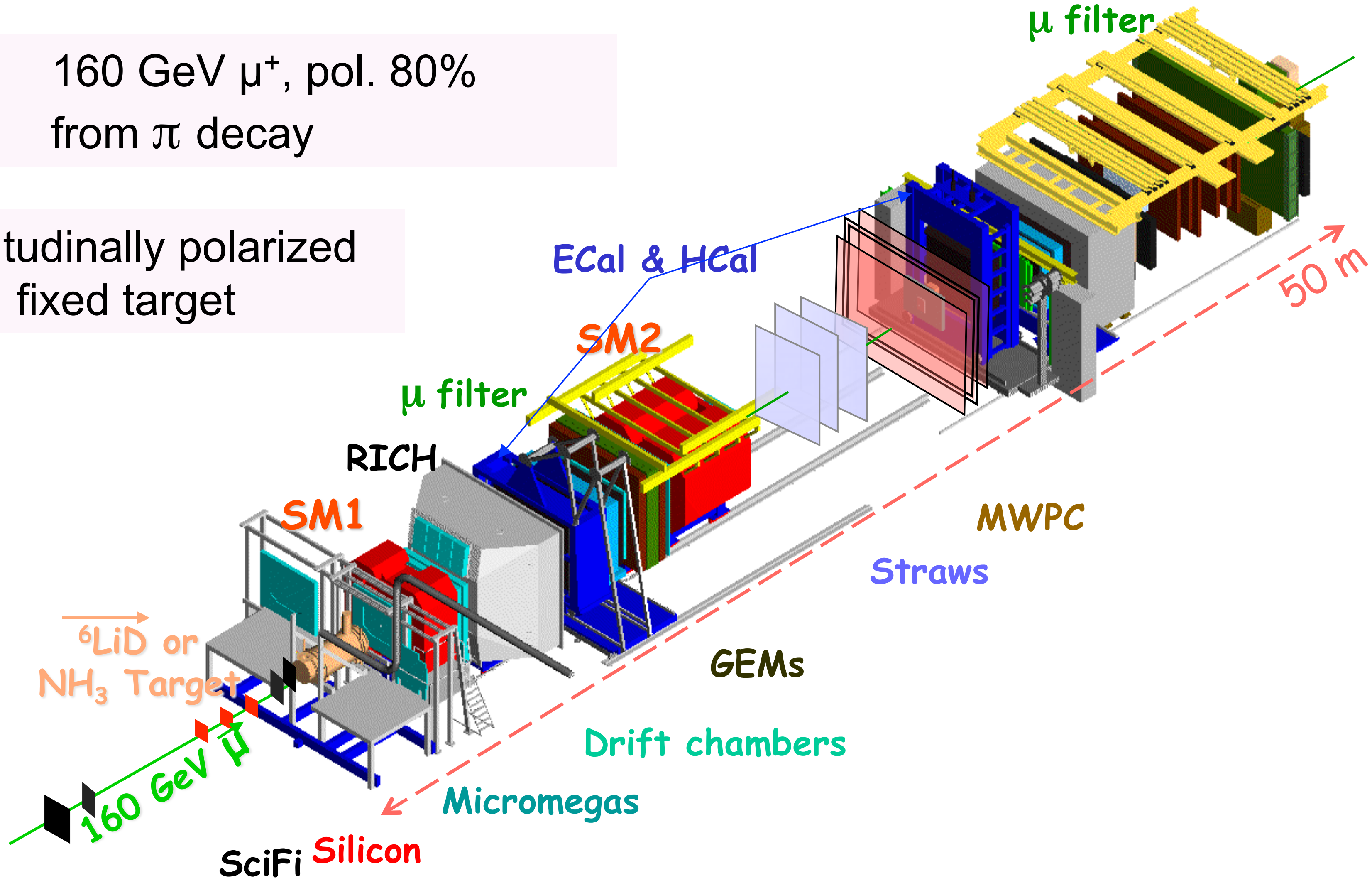
→ **Spin puzzle**

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

Compass setup 2002-2007

Beam: 160 GeV μ^+, pol. 80%
from π decay

Longitudinally polarized
fixed target



Asymmetry measurement

$$A^{\mu N} = \frac{1}{f P_\mu P_T} \frac{N_u^{\leftrightarrows} - N_d^{\leftleftarrows}}{N_u^{\leftrightarrows} + N_d^{\leftleftarrows}}$$

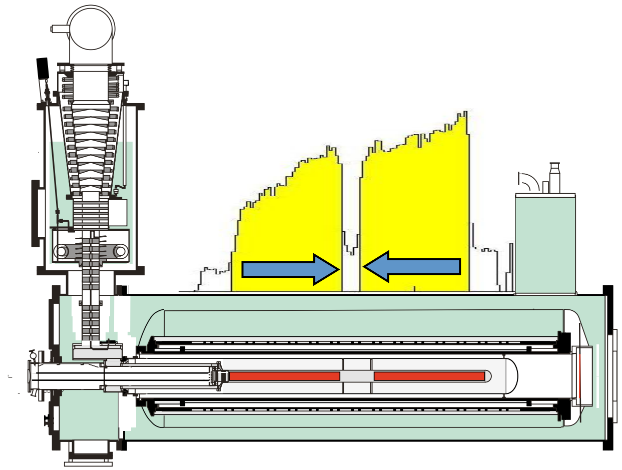
$$A^{\mu N} \approx D A_1^{\gamma N}$$

Weighting each event with $\omega = (f P_\mu D)$:

$$A_1^{\gamma N} = \frac{1}{P_T} \left(\frac{\sum_u \omega - \sum_d \omega}{\sum_u \omega + \sum_d \omega} \right)$$

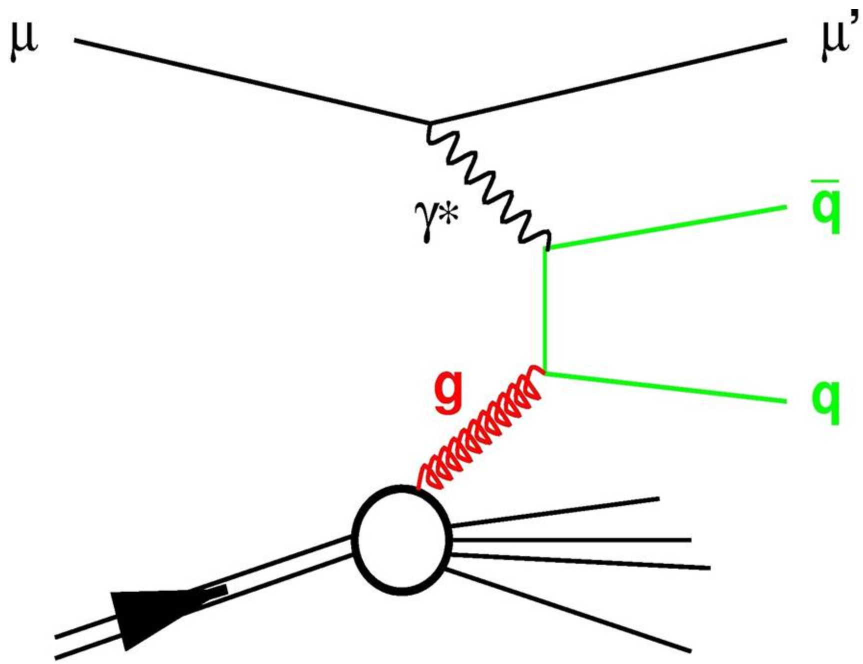
Target: ^{6}LiD (02-06) - NH_3 (2007)

P_T ~ 50% / 90%
f (dilution factor) ~ 40% / 16%
T ~ 50 mK (^{3}He / ^{4}He)



Direct measurement of ΔG/G at LO

Photon-Gluon Fusion process



$$A_{LL}^{\mu N} = R^{PGF} a_{LL}^{PGF} \frac{\Delta G}{G}$$

There are two methods to tag this process:

- **Open Charm production**
  - $\gamma^* g \to c\bar{c}$ ⇒ reconstruct D^0 mesons
  - Hard scale: M_c^2
  - No intrinsic charm in COMPASS kinematics
  - No physical background
  - Weakly Monte Carlo dependent
  - Low statistics
- **High-p_T hadron pairs**
  - $\gamma^* g \to q\bar{q}$ ⇒ reconstruct 2 jets or h^+h^-
  - Hard scale: Q^2 or Σp_T^2 [$Q^2 > 1$ or $Q^2 < 1$ $(GeV/c)^2$]
  - High statistics
  - Physical background
  - Strongly Monte Carlo dependent

High p_T pairs asymmetries $Q^2 > 1\ (\mathrm{GeV/C})^2$

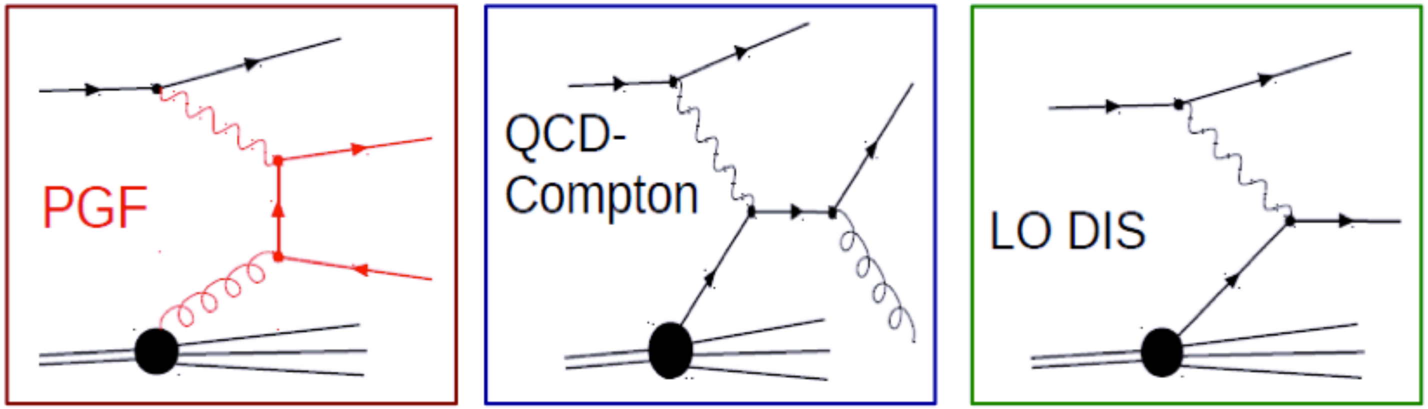
- **Two samples are considered:**

Inclusive asymmetry

$$A_1^d(x) = \frac{\Delta G}{G}(x_g)\left(a_{LL}^{PGF,inc}\frac{\sigma^{PGF,inc}}{\sigma^{Tot,inc}}\right) + A_1^{LO}(x_C)\left(a_{LL}^{C,inc}\frac{\sigma^{C,inc}}{\sigma^{Tot,inc}}\right) + A_1^{LO}(x_{Bj})\left(D\frac{\sigma^{LO,inc}}{\sigma^{Tot,inc}}\right)$$

$$A_{LL}^{2h}(x) = \left(\frac{A^{exp}}{f P_\mu P_T}\right) = \frac{\Delta G}{G}(x_g)\left(a_{LL}^{PGF}\frac{\sigma^{PGF}}{\sigma^{Tot}}\right) + A_1^{LO}(x_C)\left(a_{LL}^{C}\frac{\sigma^{C}}{\sigma^{Tot}}\right) + A_1^{LO}(x_{Bj})\left(D\frac{\sigma^{LO}}{\sigma^{Tot}}\right)$$

high-p_T hadron pairs $(p_{T1} / p_{T2} > 0.7 / 0.4\ \mathrm{GeV/c}) \Rightarrow$ enhancement of the PGF contribution



Extraction of $\Delta G/G$ from high p_T pairs

COMPASS

- The gluon polarisation is determined from two asymmetry samples: the two high-p_T hadrons and the inclusive data samples. **The final formula is:**

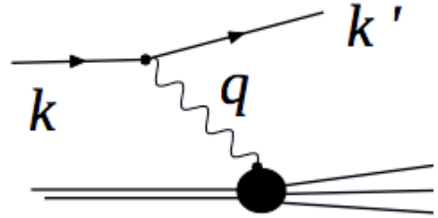
$$\frac{\Delta g}{g}(x_g) = \frac{1}{\beta}\left[A_{LL}^{2h}(x) + A_{corr}\right] \qquad A_{corr} = -\left(A_1(x_{Bj}) D \frac{R_{LO}}{R_{LO}^{inc}} - A_1(x_C)\beta_1 + A_1(x_C')\beta_2\right)$$

$$\beta = a_{LL}^{PGF} R_{PGF} - a_{LL}^{PGF,inc} R_{PGF}^{incl} \frac{R_{LO}}{R_{LO}^{inc}} - a_{LL}^{PGF,incl} \frac{R_C R_{PGF}^{inc}}{R_{LO}^{inc}} \frac{a_{LL}^{C}}{D}$$

- β_1 and β_2 are factors depending on a_{LL}^{i} and R_i
- Each event is weighted with $\omega = f D P_\mu \beta$ → statistical improvement!
- The following parameters are obtained from Monte Carlo, and then they are parameterised event-by-event by a Neural Network (to allow for their use in data):

R_{PGF}, R_C, R_{LO}, R_{PGF}^{inc}, R_C^{inc}, R_{LO}^{inc}, a_{LL}^{PGF}, a_{LL}^{C}, a_{LL}^{LO}, $a_{LL}^{PGF, inc}$, $a_{LL}^{C, inc}$ and $a_{LL}^{LO, inc}$

Event selection



- Interaction vertex which contains an incoming and an outgoing muon
- For DIS variables: $Q^2>1\ (GeV/c)^2$ and $0.1 < y < 0.9$

⇒ This selection constitutes the inclusive sample

- Events with at least 2 outgoing hadrons are selected
- The hadrons of the high p_T pair are required to have:

$$p_{T1} > 0.7\ GeV/c\ ,\ \ p_{T2} > 0.4\ GeV/c$$

$$z_1 + z_2 < 0.95$$

⇒ All this selection produces the high p_T sample

$$Q^2=-q^2$$
$$q=k-k'$$
$$\nu=E-E'$$
$$y=\frac{\nu}{E}$$
$$x=\frac{Q^2}{2M\nu}$$

Years	2002	2003	2004	2006	all years
Statistics	450 K	1.3 M	2.8 M	2.7 M	7.3 M

Events

Monte Carlo tuning

- The purpose of the MC tuning is to correct the shapes of the hadron variables (momenta) and fragmentation (multiplicity).
- In LEPTO this can be achieved by changing JETSET parameters:

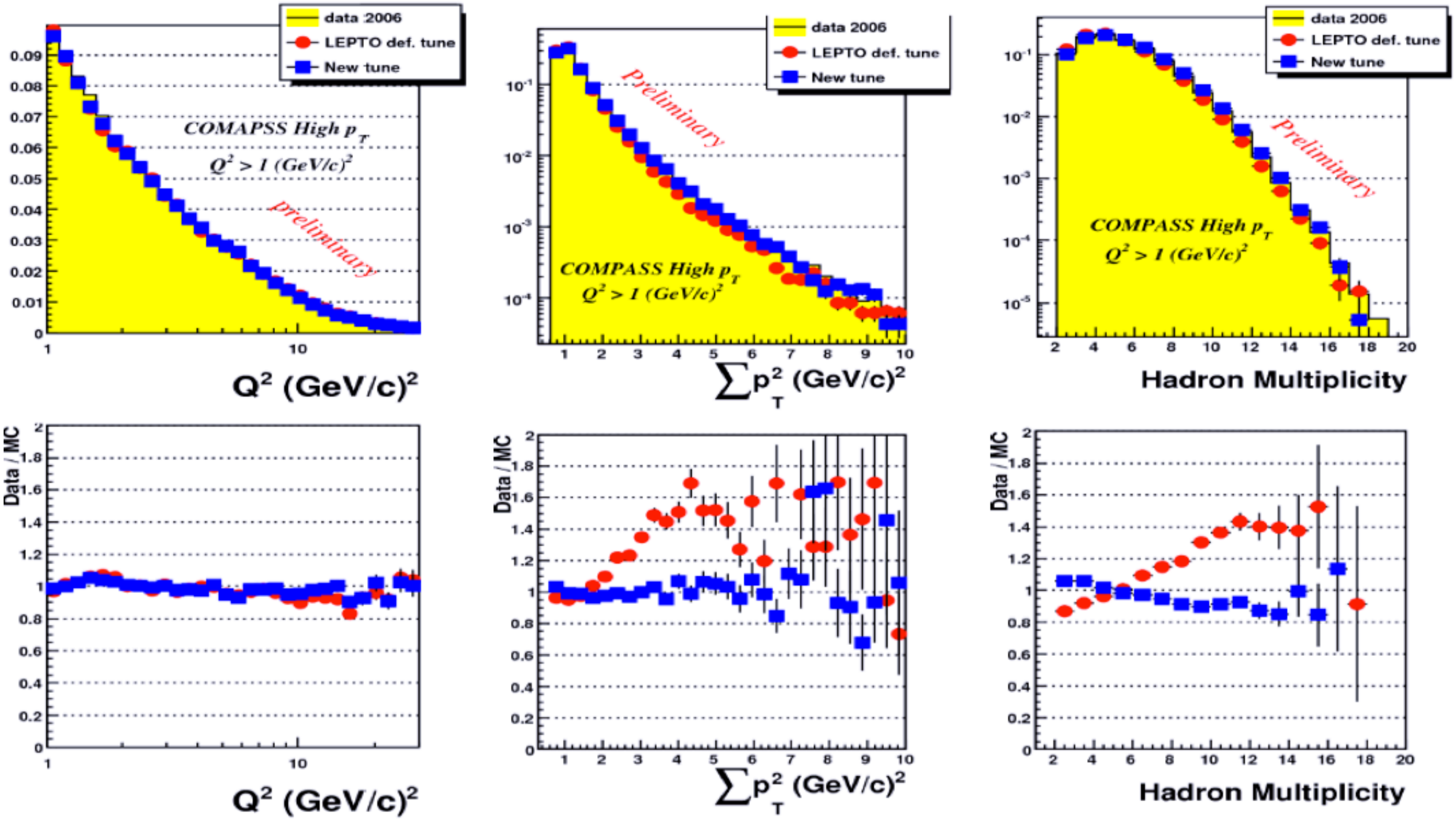
PARJ(21)	PARJ(23)	PARJ(24)	PARJ(41)	PARJ(42)
Transverse momentum of the hadron fragmentation			Fragmentation function	

- These parameters can be divided into two sets regarding the component of the trajectory of the particles: Transverse and longitudinal variable components.
- The sets can be tuned independently.

⇒ The tuning improves substantially the Data-MC agreement.

Data vs Monte Carlo comparison

Monte Carlo (PS on): LEPTO generator with PDFs from MSTW2008LO

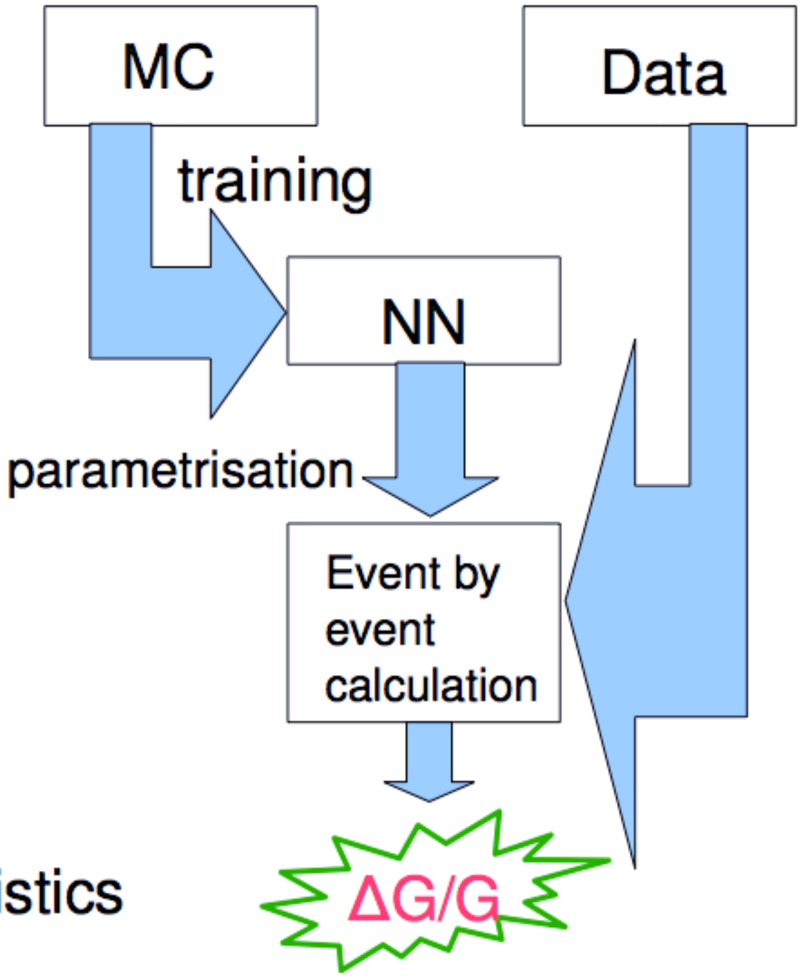


The impact of this tunning is included in the systematic error

Weighted method: Neural network training

A Neural Network is used to assign to each event a probability to be originated from each of the three processes (LO, PGF or Compton).

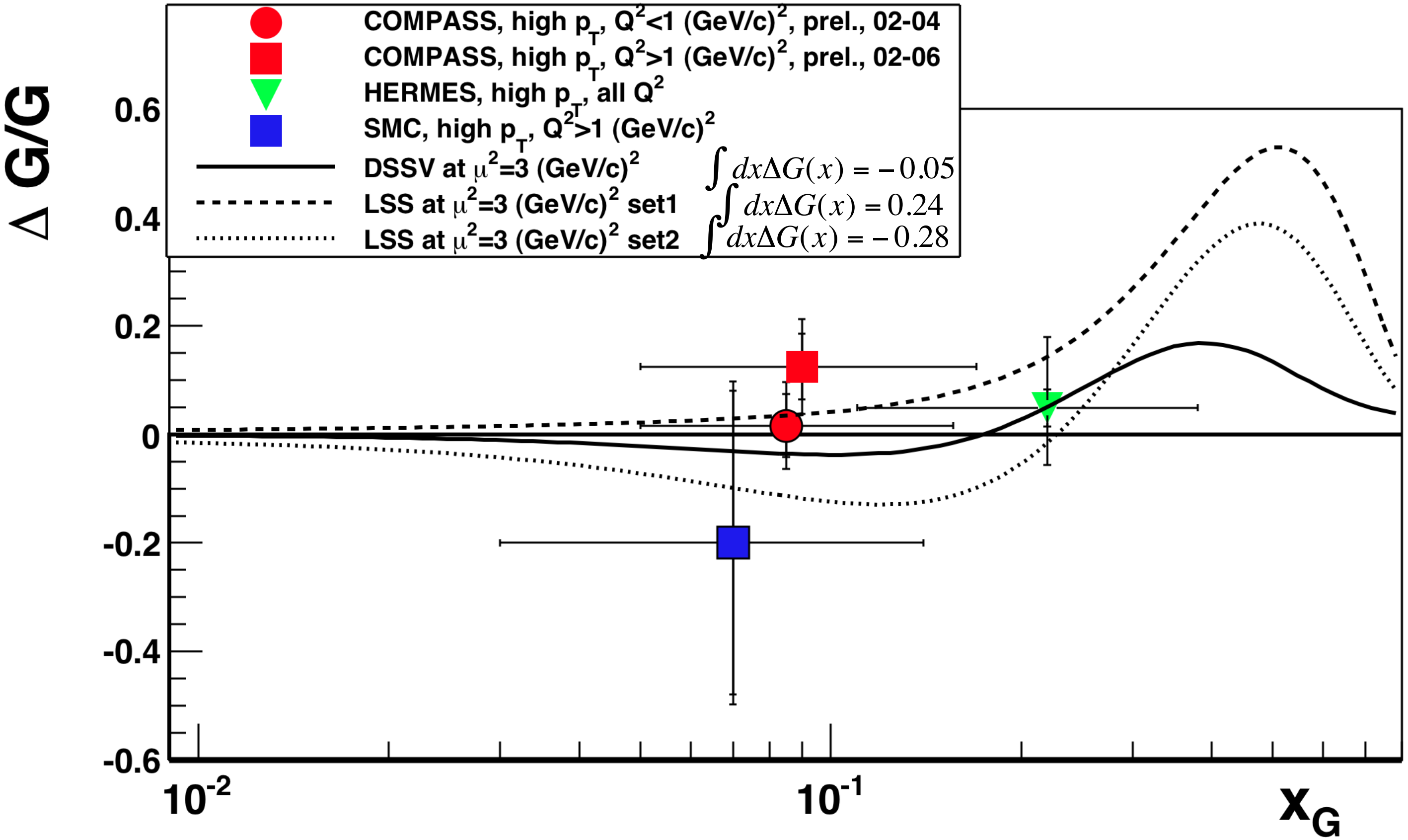
- A MC sample is used to train the Neural Network (NN).
- A parametrisation is constructed for all variables involved in the weight.
- A Data sample is weighted on an event-by-event basis.



Optimal usage of the data sample statistics

LO $\Delta G/G$ results high p_T $Q^2 > 1$ (GeV/c)^2

$$\frac{\Delta G}{G} = 0.125 \pm 0.060 \pm 0.063 \qquad x_G = 0.09^{+0.08}_{-0.04} \qquad \langle \mu^2 \rangle = 3.4\ (\mathrm{GeV/c})^2$$



DSSV: D. de Florian et al., Phys. Rev. D80(2009)034030

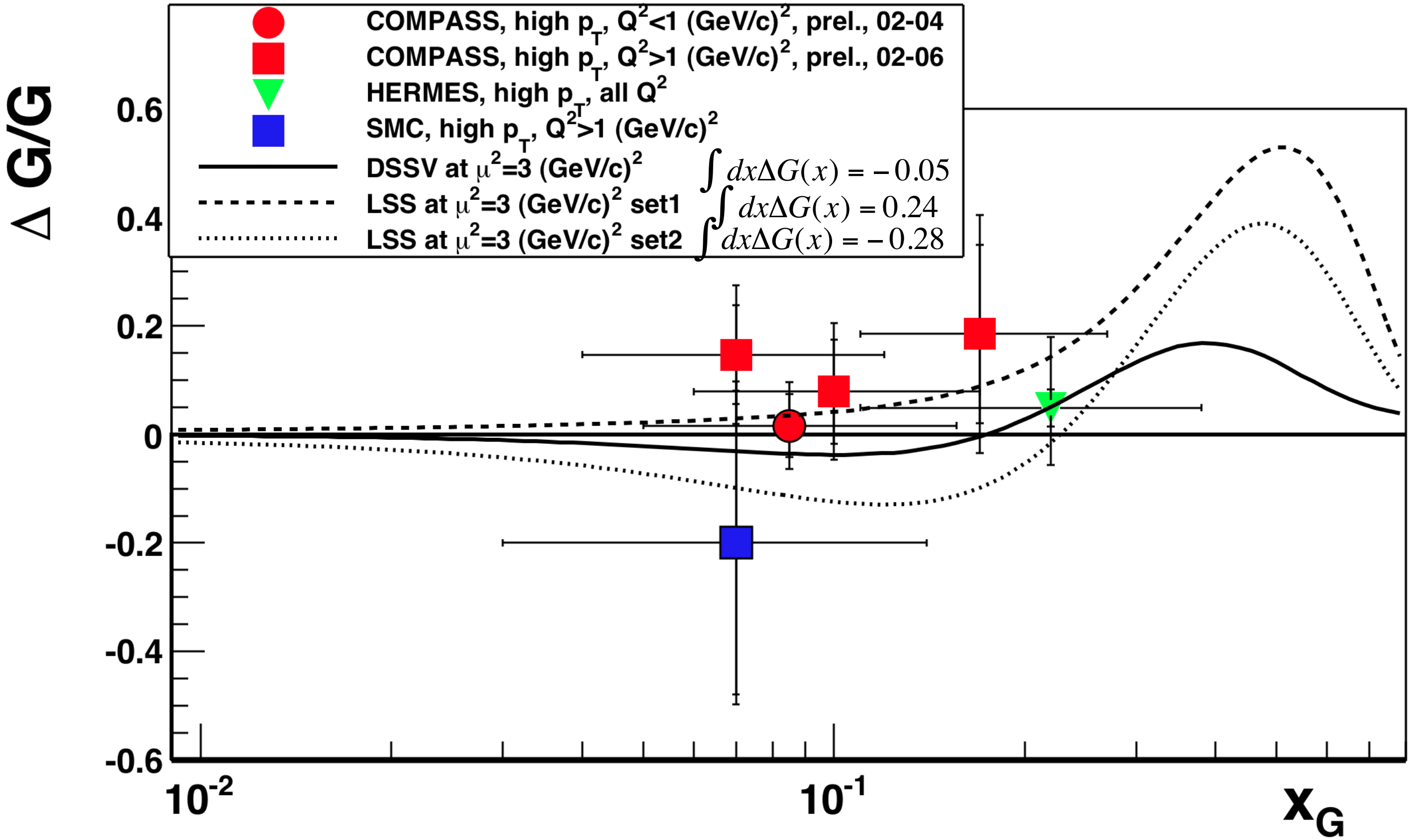
LSS: E. Leader, A.V. Sidorov, D.B. Stamenov, arXiv 1010.5742(2010)

LO $\Delta G/G$ results high p_T $Q^2 > 1\ (GeV/c)^2$

1st point : $0.147 \pm 0.091_{stat} \pm 0.088_{sys}$ @ $x_g = 0.07^{+0.05}_{-0.03}$

2nd point : $0.079 \pm 0.096_{stat} \pm 0.082_{sys}$ @ $x_g = 0.10^{+0.07}_{-0.04}$

3rd point : $0.185 \pm 0.165_{stat} \pm 0.143_{sys}$ @ $x_g = 0.17^{+0.10}_{-0.06}$

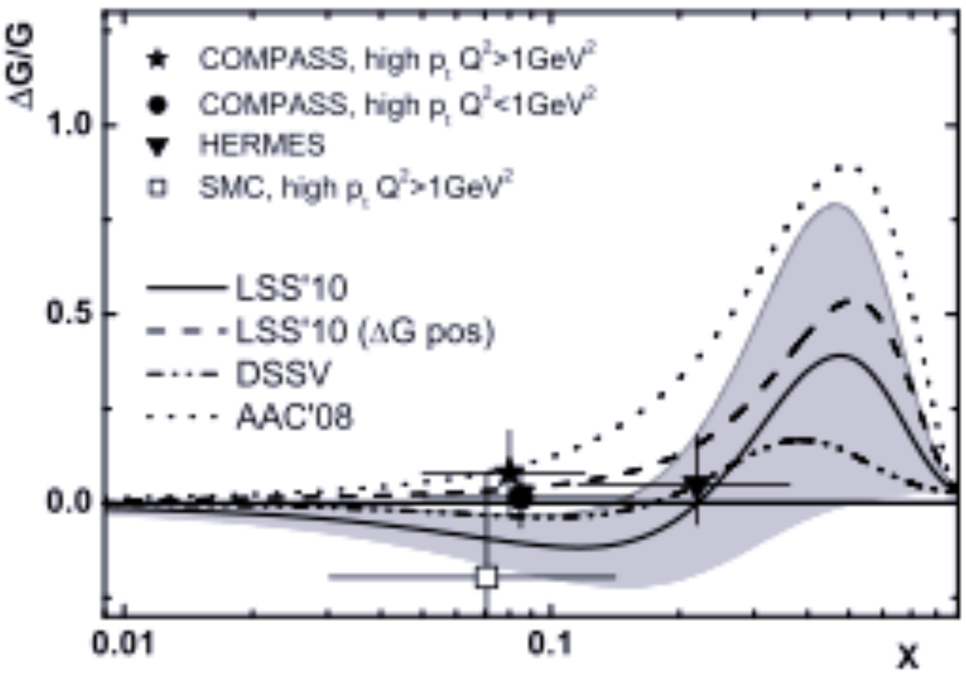


Comparison to NLO fits to DIS & SIDIS

LSS: E. Leader, A.V. Sidorov, D.B. Stamenov, arXiv 1010.5742(2010)

TABLE IV: First moments of polarized PDFs at $Q^2 = 4\ GeV^2$. The corresponding DSSV values are also presented.

Fit	$\Delta\bar{s}$	ΔG	$\Delta\Sigma$
LSS10 (pos $x\Delta G$)	-0.063 ± 0.004	0.316 ± 0.190	0.207 ± 0.034
LSS10 (node $x\Delta G$)	-0.055 ± 0.006	-0.339 ± 0.458	0.254 ± 0.042
DSSV (node $x\Delta G$)	-0.056	-0.096	0.245



$$
\begin{aligned}
J_z = \frac{1}{2} &= \frac{1}{2}\Delta\Sigma(Q^2) + \Delta G(Q^2) + L_z(Q^2) \\
&= -0.21 \pm 0.46 + L_z(Q^2) \quad (\text{node } \Delta G) \\
&= \quad 0.42 \pm 0.19 + L_z(Q^2) \quad (\text{pos } \Delta G).
\end{aligned}
$$

Conclusion

•New extraction of ΔG/G at LO from high p_T pairs at $Q^2 > 1$ (GeV/c)^2 and x_G [0.04-0.27]

•Compatible with 0 and global QCD fits at NLO:

-large ΔG (2-3) excluded ($a_0 = \Delta\Sigma - n_f \frac{\alpha_s}{2\pi} \Delta G$)

-still large error bars, and no NLO treatement

→ not constraining the spin puzzle

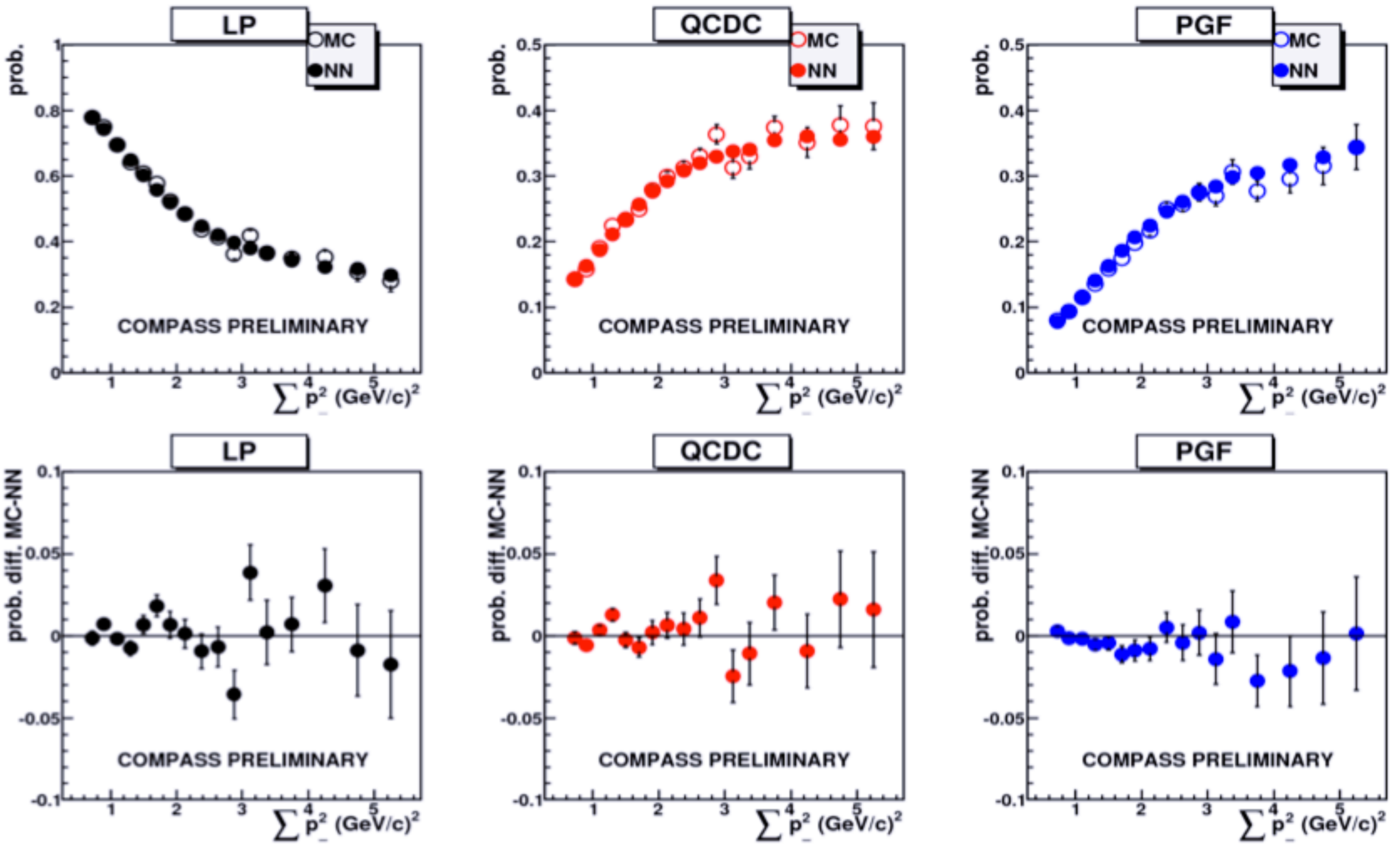
•Still to come:

-ΔG/G from single high p_T hadrons at $Q^2 < 1$ (GeV/c)^2 with NLO treatement at COMPASS energies.

Spares

Stability checks of Neural Network

We parametrise the R^i fractions as probabilities.



DSSV NLO fits to DIS & SIDIS