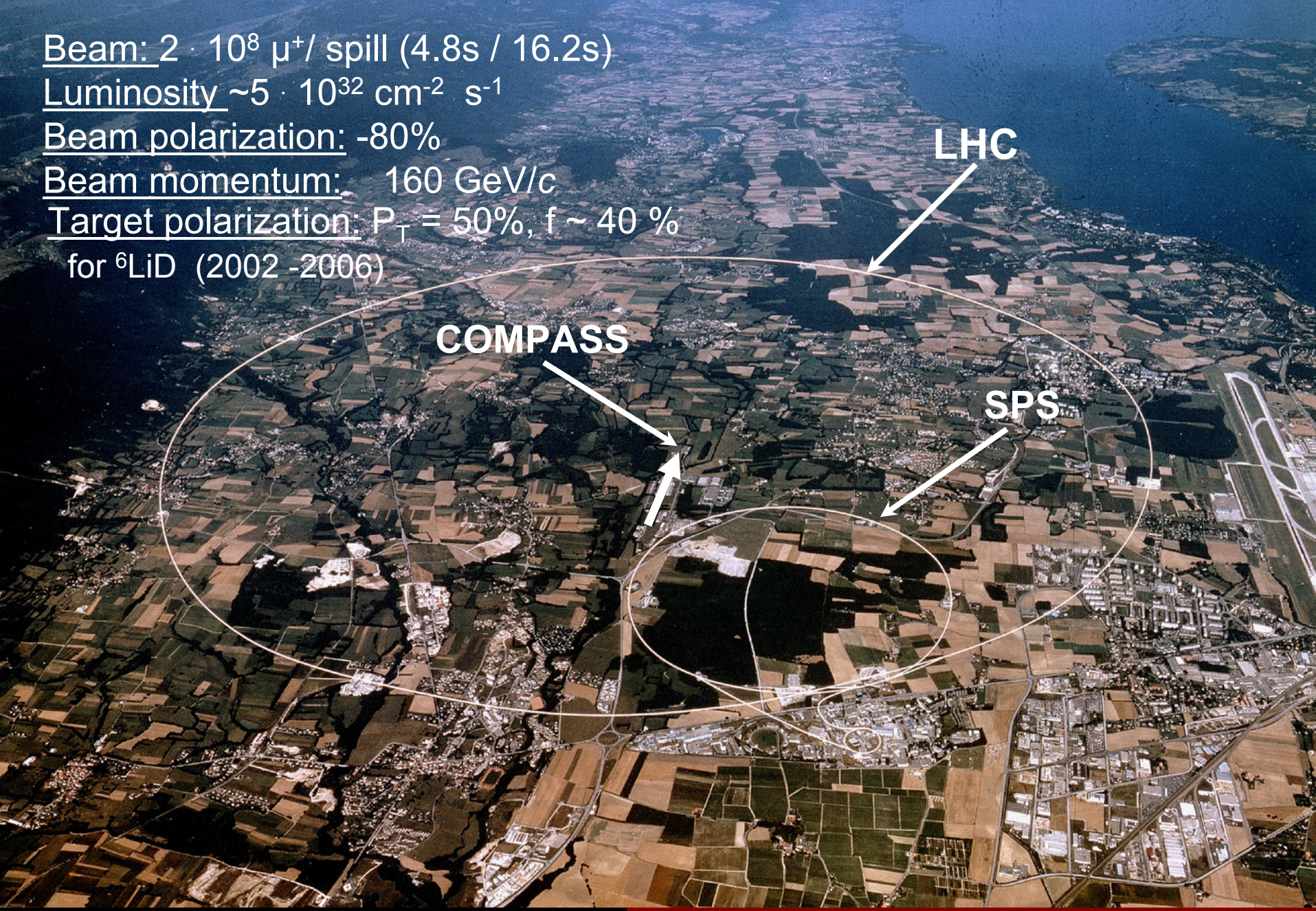
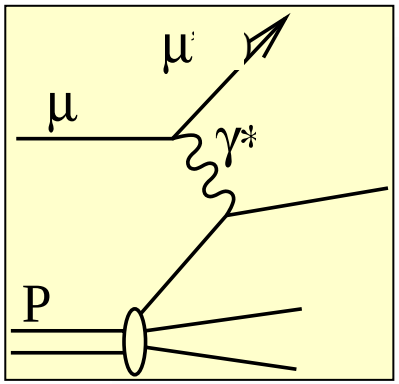
Gluon polarisation in the Nucleon from high transverse momentum hadron pairs at COMPASS.

Krzysztof Kurek
Andrzej Sołtan Institute for Nuclear Studies, Warsaw, Poland

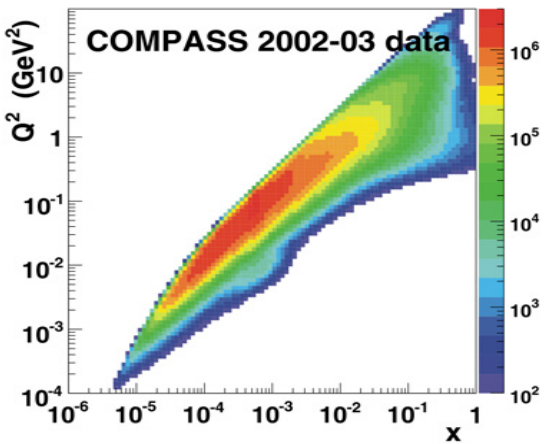
On behalf of the COMPASS Collaboration


Beam: 2 · 10^8 μ+/ spill (4.8s / 16.2s)
Luminosity ~5 · 10^32 cm^-2 s^-1
Beam polarization: -80%
Beam momentum: 160 GeV/c
Target polarization: P_T = 50%, f ~ 40 %
for 6LiD (2002 -2006)
LHC
COMPASS
SPS

COMPASS in muon run
NIM A 577(2007) 455



Trigger Hodoscopes
ECALs & HCALs
MWPCs
SM2
RICH
SM1
Drift Chambers
^{6}LiD target
μ Filters/
Walls
Straws
GEMs
Micromegas
Si
SciFi
veto
160 GeV μ
50 m



Introduction

New results from $Q^2 > 1(GeV/c)^2$ analysis

- Determination of the gluon polarization
- Data selection
- Neural Network (NN) approach
- Data and MC comparison
- Systematics studies and results

$Q^2 < 1\ (GeV/c)^2$ analysis

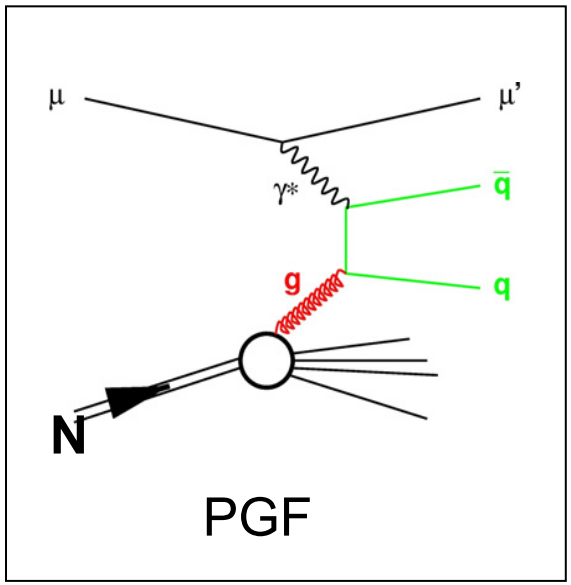
- Methods and results

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

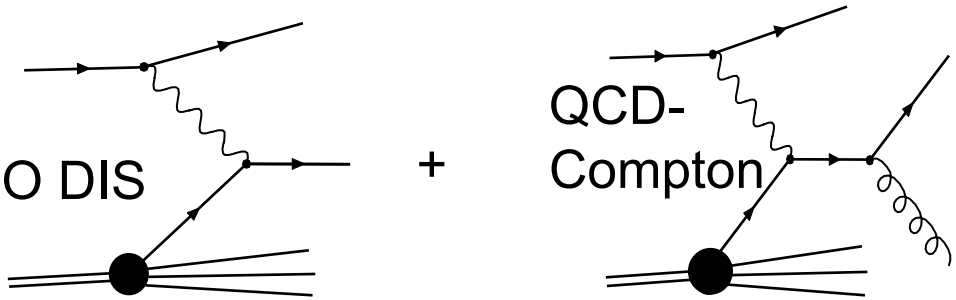
Conclusions and Outlook

The simple idea: 3 basic processes PGF „probes" gluons

R.D.Carlitz, J.C.Collins and A.H.Mueller, Phys.Lett.B 214, 229 (1988)
Revisited by A.Bravar,D.von Harrach and A.Kotzinian, Phys.Lett.B 421, 349 (1998)
Applied by SMC, HERMES and COMPASS

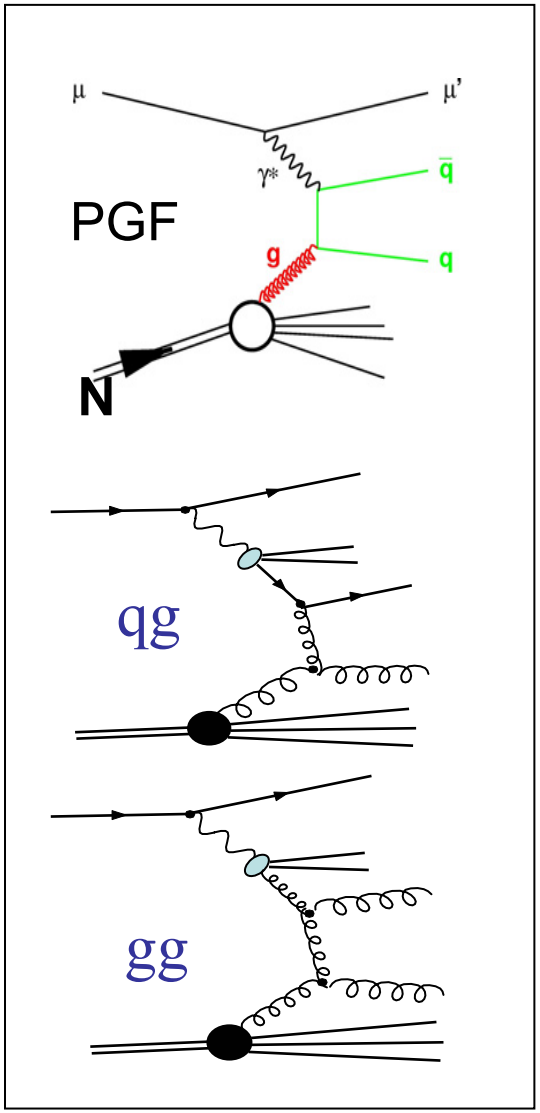


+ LO DIS +



$$A_{LL}^{2h}(x_{Bj}) \approx \frac{\Delta G}{G}(x_G)\hat{a}_{LL}^{PGF} R_{PGF} + A_1^{LO}(x_C)\hat{a}_{LL}^{C} R_C + A_1^{LO}(x_{Bj}) D R_L \qquad A_1^{LO} \equiv \frac{\sum_i e_i^2 \Delta q_i}{\sum_i e_i^2 q_i}$$

four additional sub-processes, from so-called resolved photon



+ LO DIS + QCD-Compton +

+ qq + gq +

Important for Low Q^2 analysis ($Q^2<1(GeV/c)^2$)

The basis of the analysis

- The high-p_T hadron pairs analysis is MC dependent and requires very good agreement between data and MC.
- Here MC generator is an effective model of Physics and contains three basic elements:
  structure of nucleon,
  hard sub-processes,
  fragmentation.
- The perturbative scale for low Q^2 analysis is a Σp_T^2 while for high Q^2 analysis the scale is determined by Q^2 and cuts on hadron's p_T can be relaxed.
- The analysis are done in LO approximation – NLO effects are partially taken into account via parton shower concept in MC.
- The advantage of the analysis is high statistics.

The extraction formula for the gluon polarisation

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

$$\beta = \left[a_{LL}^{PGF} R_{PGF} - a_{LL}^{PGF,incl} R_{PGF}^{incl} \right] \left(\frac{R_L}{R_L^{incl}} + \frac{R_C}{R_L^{incl}} \frac{a_{LL}^C}{D} \right)$$

$$A^{corr} = -A_1(x_{Bj}) D \frac{R_L}{R_L^{incl}} - A_1(x_C)\beta_1 + A_1(x'_C)\beta_2$$

$$\beta_1 = \frac{1}{R_L^{incl}} \left(a_{LL}^C R_C - a_{LL}^{C,incl} R_C^{incl} \frac{R_L}{R_L^{incl}} \right) \qquad \beta_2 = a_{LL}^{C,incl} \frac{R_C R_C^{incl}}{(R_L^{incl})^2} \frac{a_{LL}^C}{D}$$

R's are fractions of the sub-processes (LO,PGF, QCDC) in high-p_T and inclusive samples, respectively

a_{LL} 's are so-called analysing powers for LO,PGF and QCDC (the ratio of partonic polarised and unpolarised cross sections for sub-processes)

D is a depolarization factor.

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Note that inclusive sample also contains PGF and QCDC as well as LO process

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- All convolution integrals are correctly taken into account and give averaged quantites; here for simplicity of the notation average symbols are not explicitely written.
- The polarised quark contribution (LO+QCDC) are taken directly from inclusive A_1 asymmetry (pure data)
- To determine $\Delta G/G$ ($\langle x_G \rangle$) from $\langle \Delta G/G \rangle$, $\Delta G/G$ has been assumed to be a linear function of x_G in measured bin
  (very well justified assumption)

Data selection for $Q^2 > 1 (GeV/c)^2$

- Cuts on inclusive variables:
  $Q^2 > 1$ (GeV/c)^2 (Scale of the process)
  $0.1 < y < 0.9$
- Cuts on hadronic variables:
  $p_{T1} > 0.7$ GeV/c and $p_{T2} > 0.7$ GeV/c
  $x_{F1,2} > 0$, $z_{1,2} > 0$, $z_1 + z_2 < 0.95$
  inv. mass of two hadrons > 1.5 (GeV/c)^2

Total number of events in the selected sample: ~500 kevents

Weighted method for $\Delta G/G$ extraction

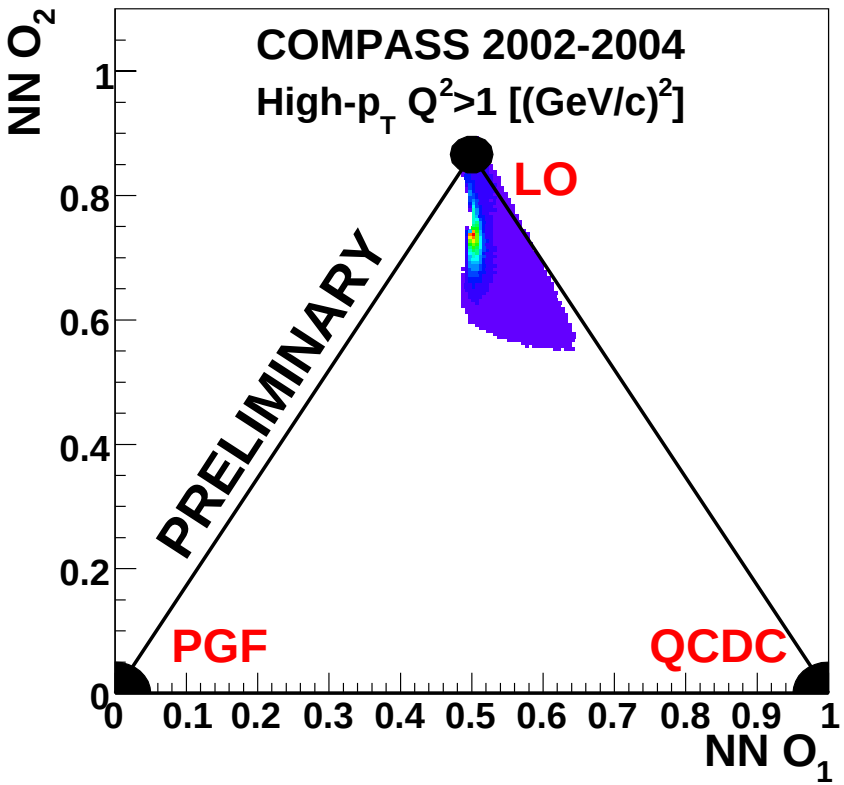
The following factors we need to know on the event by event basis:

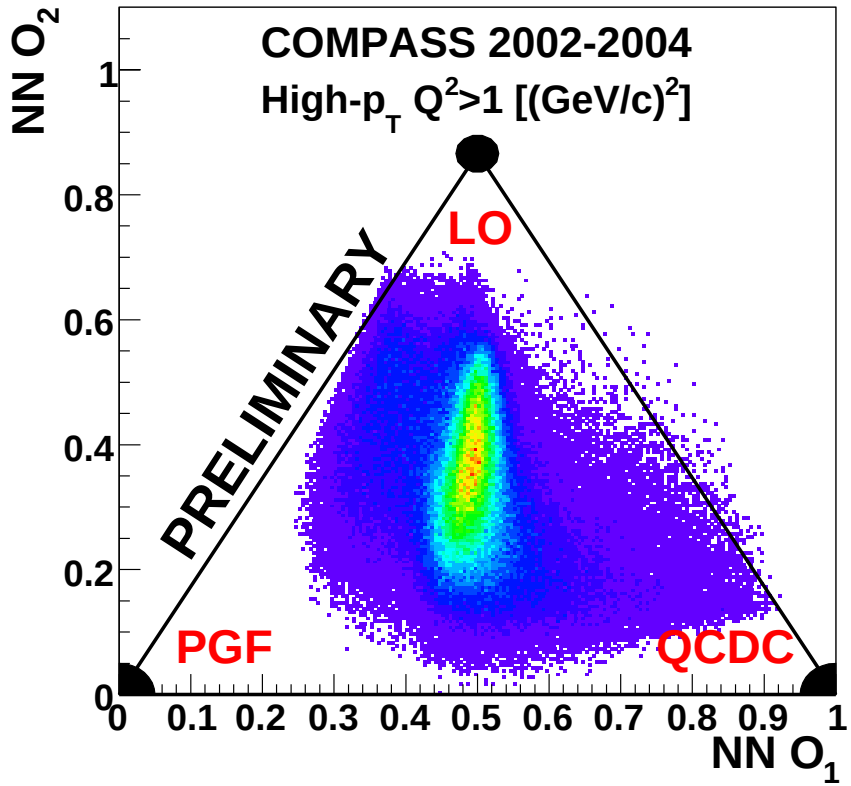
$$R_{PGF}, R_C, R_L, R_{PGF}^{incl}, R_C^{incl}, R_L^{incl},$$
$$a_{LL}^{PGF}, a_{LL}^{PGF,incl}, a_{LL}^{C}, a_{LL}^{C,incl},$$
$$x_C, x_G, \quad f,\ D, P_b$$

- f, D, P_b can be directly obtained from data
- Remainning factors have to be obtained from MC
- NN trained on MC samples is used for parameterization of these quantities
  Input variables for NN:
  - inclusive case: x_{Bj} and Q^2
  - high-p_T: x_{Bj} ,Q^2,$p_{L1,2}$,$p_{T1,2}$
- Weight used: $fDP_b\beta$
- Good data description with MC is a „key point” of the analysis

NN parameterization of R's

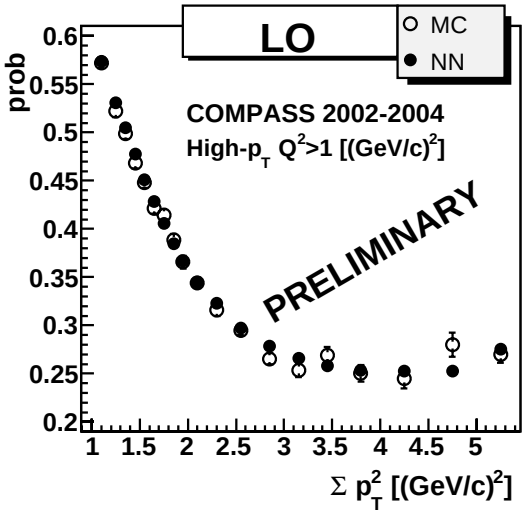
2 variables o_1 and o_2 are used (R's sum up to 1)

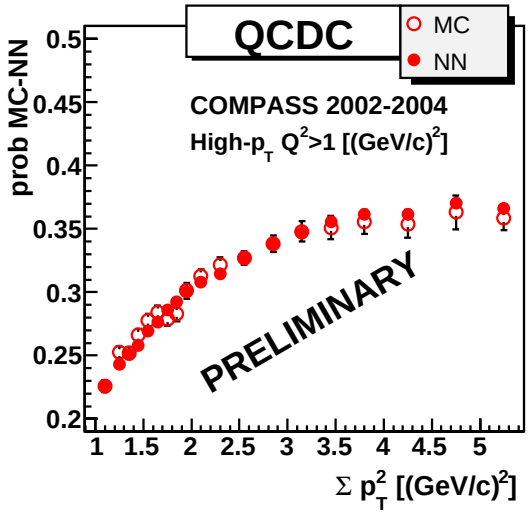


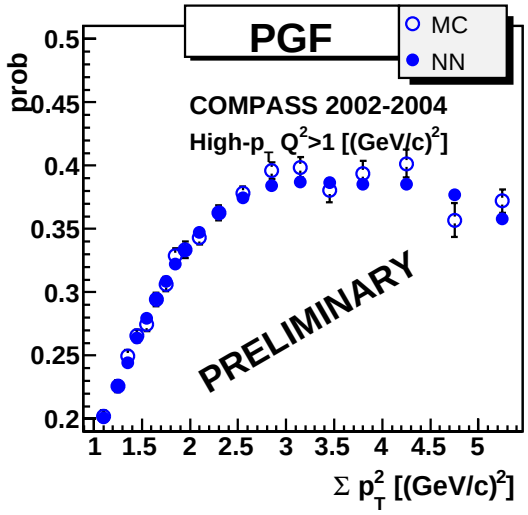


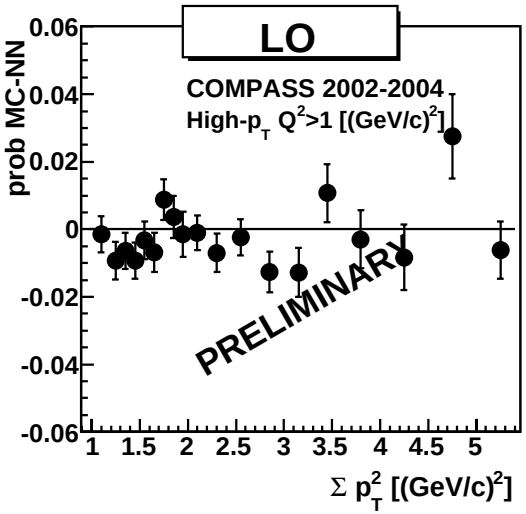
$$R_{PGF} = 1 - o_1 - \frac{1}{\sqrt{3}} o_2 \qquad R_C = o_1 - \frac{1}{\sqrt{3}} o_2 \qquad R_L = \frac{2}{\sqrt{3}} o_2$$

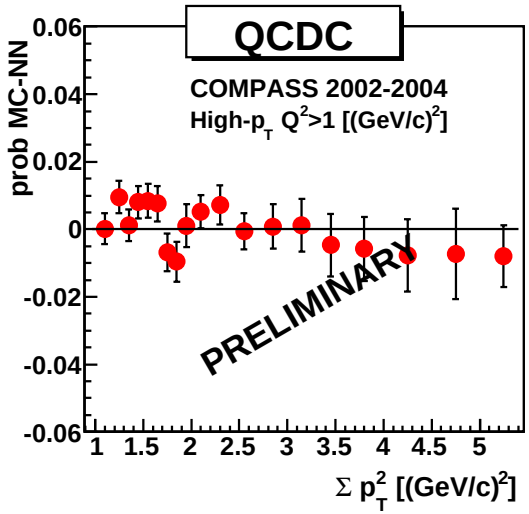
NN stability

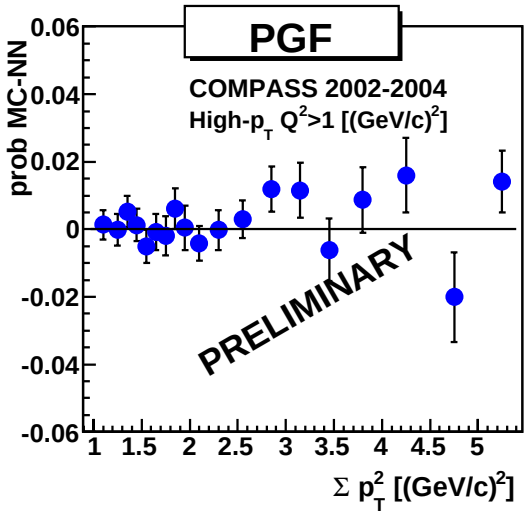












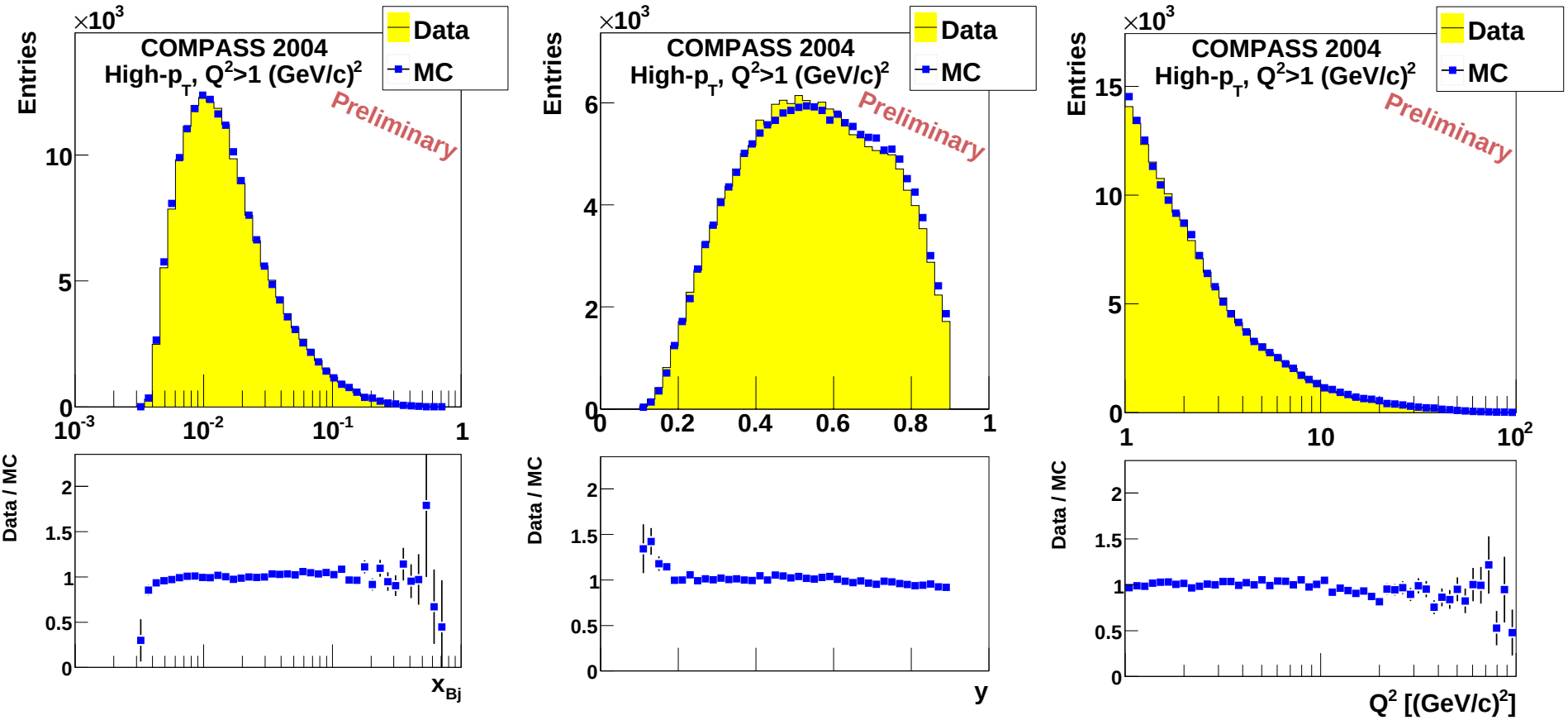
MC simulations

- 2 MC samples were used in the analysis: high-p_T and inclusive
- Input: LEPTO generator and full simulation of the detector
  PDFs: MRST2004LO
- Gluon radiations in final and initial states – simulation of the part of NLO corrections:
  - Parton Shower on were used for $\Delta G/G$ extraction (means NN training)
  - Parton Shower off were tested and included in the systematics
- To improve data/MC agreement - LEPTO was tuned (k_T and parameters of fragmentation)
- Default MC parameters were used in systematics studies

	PARJ21	PARJ23	PARJ214	PARJ41	PARJ42
Default	0.36	0.01	2.0	0 .3	0.58
Compass	0.3	0.02	3.5	0.6	0.1

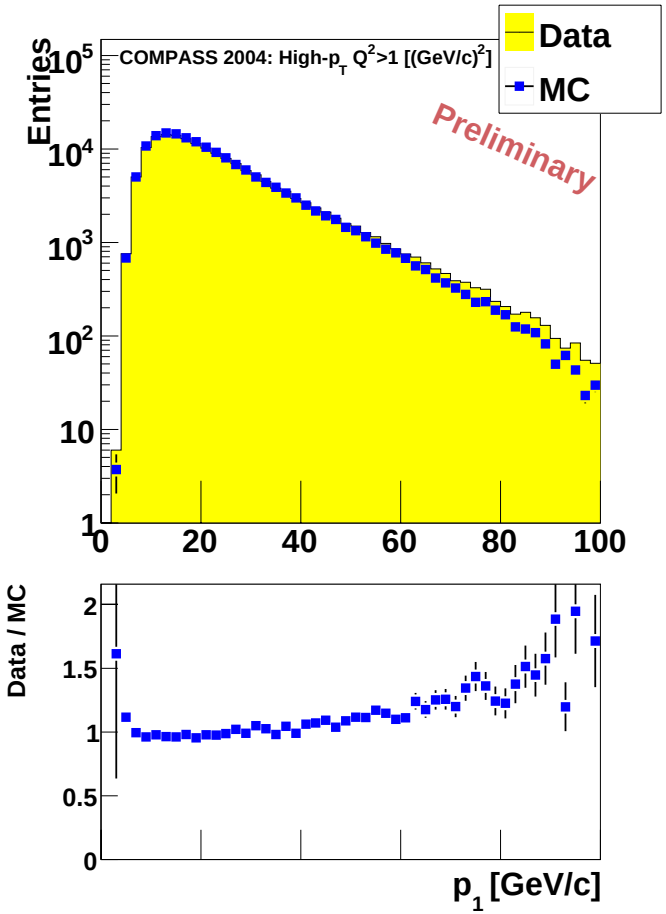
	Final MC
$\langle a^{LO} \rangle$	0.63
$\langle a^{C} \rangle$	0.50
$\langle a^{PGF} \rangle$	-0.36
R_L	0.40
R_C	0.29
R_{PGF}	0.31

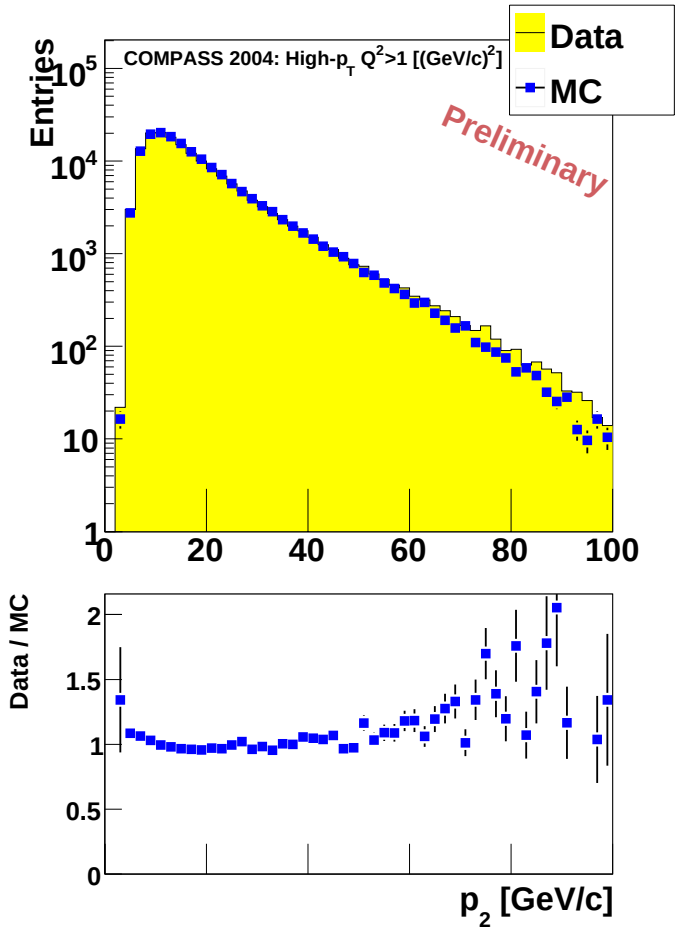
Data and MC comparison



Comparison: MC/data for high p_T sample; x,y and Q^2

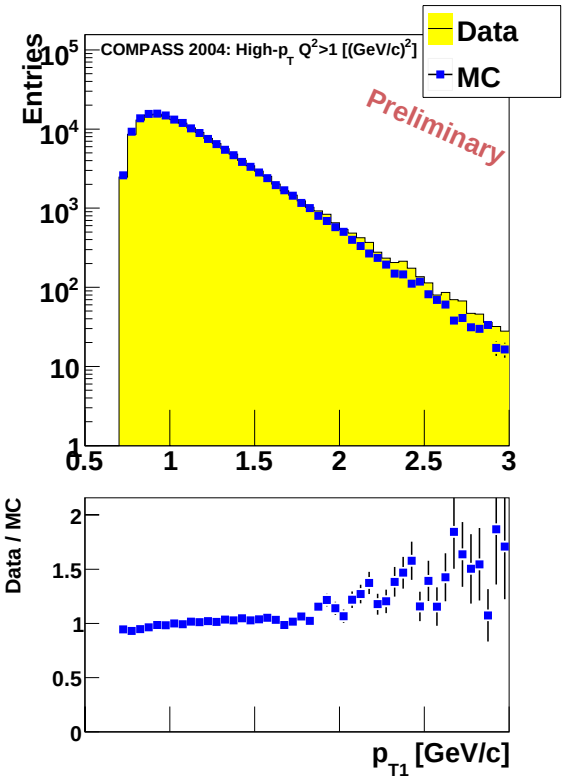
Data and MC comparison

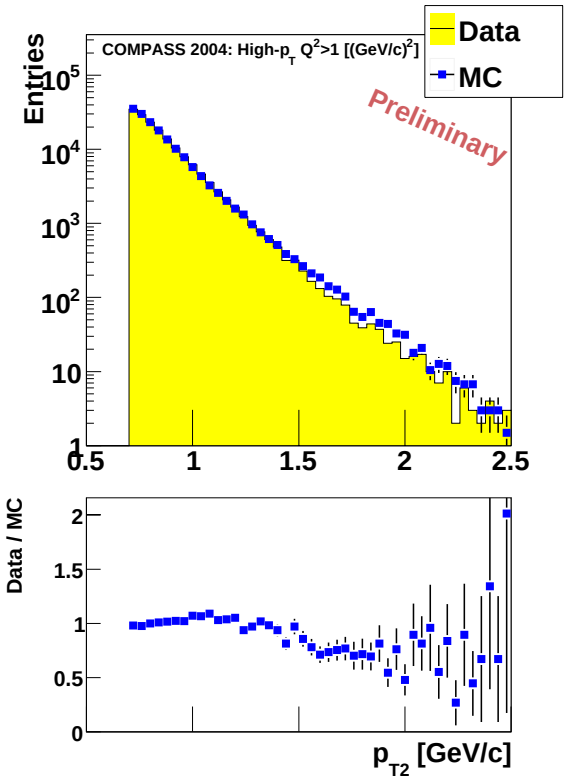


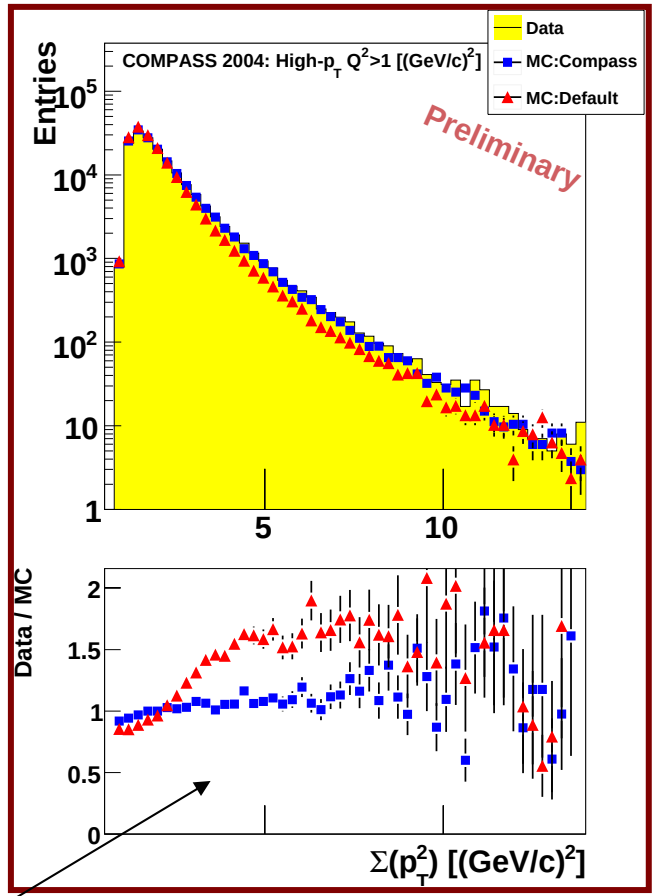


Comparison: MC/data for high p_T sample;
momenta of leading and sub-leading hadrons.

Data and MC comparison







Comparison: MC/data for high p_T sample; transverse momenta of leading and sub-leading hadrons

Impact of MC tuning

Systematics studies

What has been checked:

- False asymmetries
- NN stability
- systematic errors due to MC
- δP_b ,δP_t ,δf
- Radiative corrections
- Simplification of the formula for $\Delta G/G$

$\delta(\Delta G/G)_{NN}$	0.006
$\delta(\Delta G/G)_{MC}$	0.040
$\delta(\Delta G/G)_{f,Pb,Pt}$	0.006
$\delta(\Delta G/G)_{false}$	0.011
$\delta(\Delta G/G)_{A1}$	0.008
$\delta(\Delta G/G)_{formula}$	0.013
Total	0.045

Systematics errors due to MC

4 different MC's have been used:

- COMPASS tuning PS on
- COMPASS tuning PS off
- standard tuning PS on
- standard tuning PS off

For every MC sample 3 different analysis have been performed to extract $\Delta G/G$:

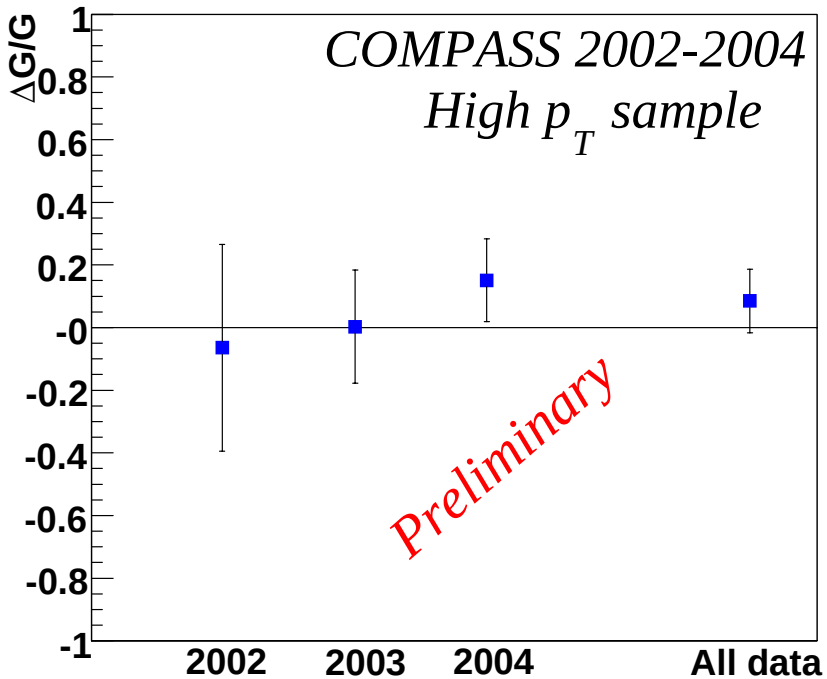
1. Standard MC events are used and $\Delta G/G$ is extracted
2. Limited sample is used for $\Delta G/G$ extraction
   (events with good data/MC agreement)
3. MC events re-weighted to obtain the ratio of data/MC =1

Final result for the error: 0.04

Preliminary result for gluon polarisation for $Q^2 > 1\ (GeV/c)^2$

$$\frac{\Delta G}{G} = 0.08 \pm 0.10 \pm 0.05$$

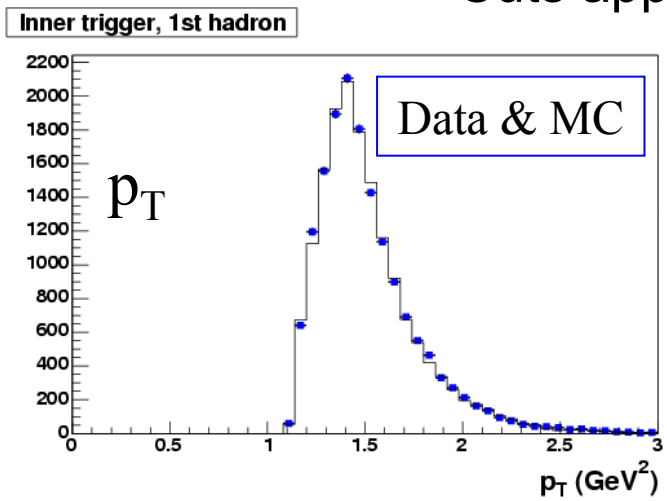
$$x_G = 0.082^{+0.041}_{-0.027} @ \mu^2 \approx 3(GeV/c)^2$$

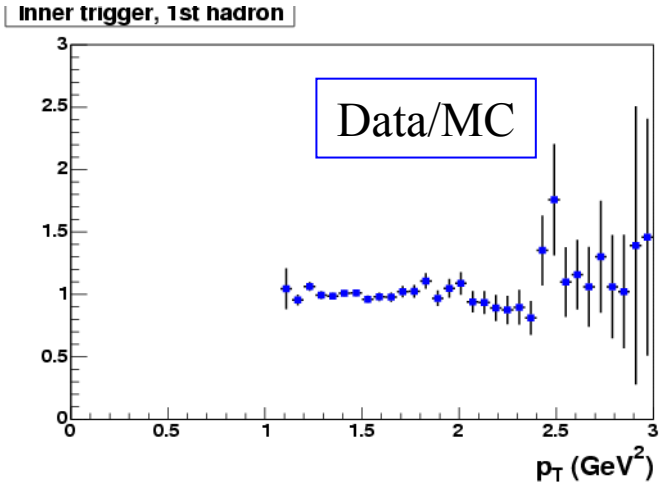


Plot has statistical errors only

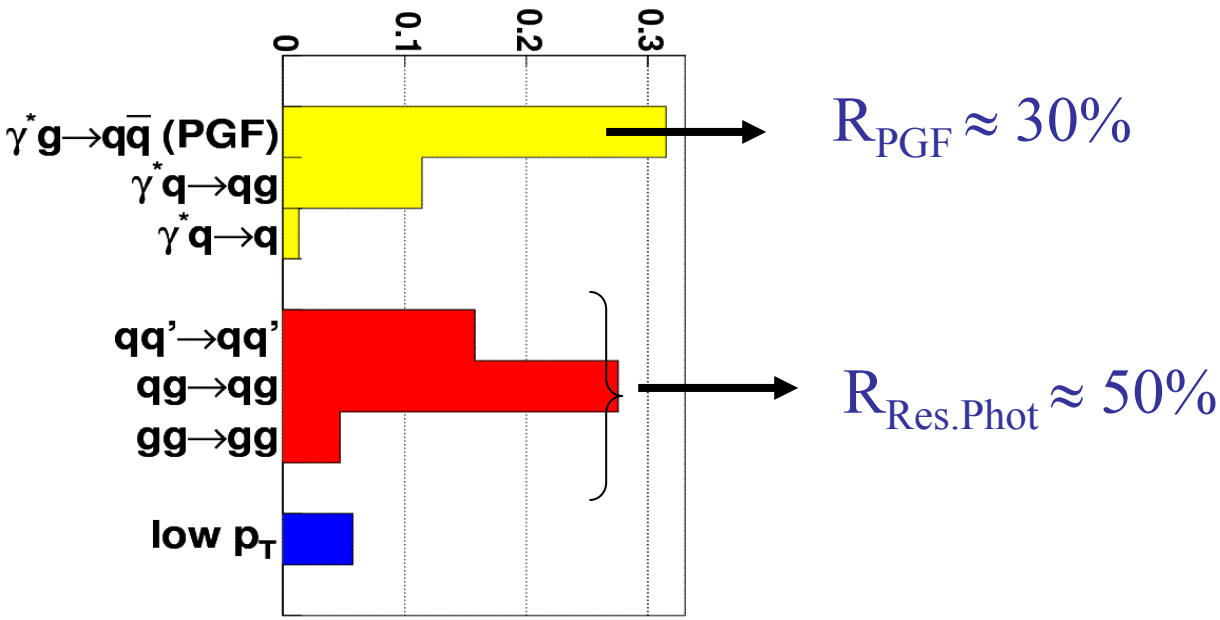
Low Q^2 analysis (Q^2 <1 $(GeV/c)^2$)

Cuts approach used – cut on $\Sigma p_T^2 > 2.5$ $(GeV/c)^2$



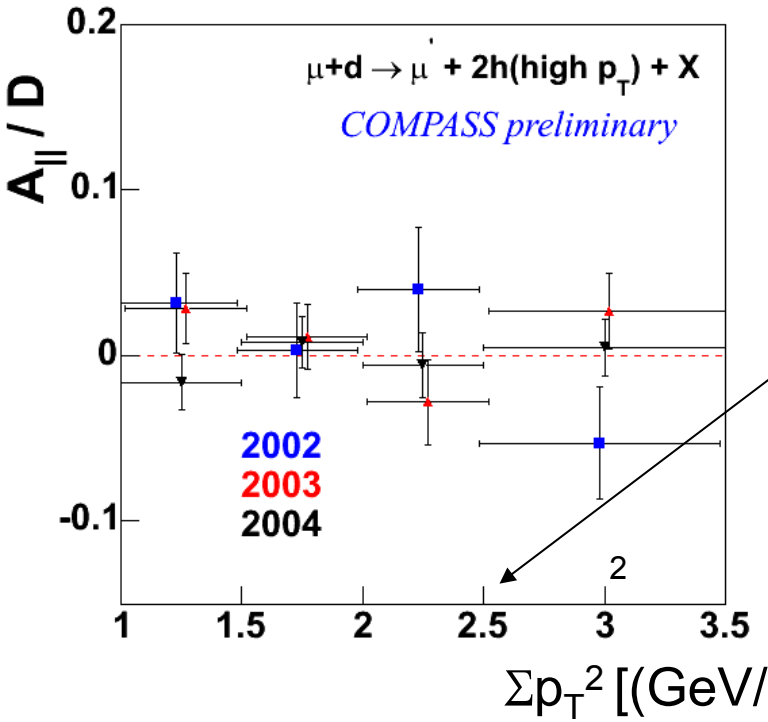


PYTHIA generator for low Q^2 + spectrometer simulation.



Here LO processes as well as low p_T part have been neglected in the analysis

Result for gluon polarisation for $Q^2 < 1$ (GeV/c)^2

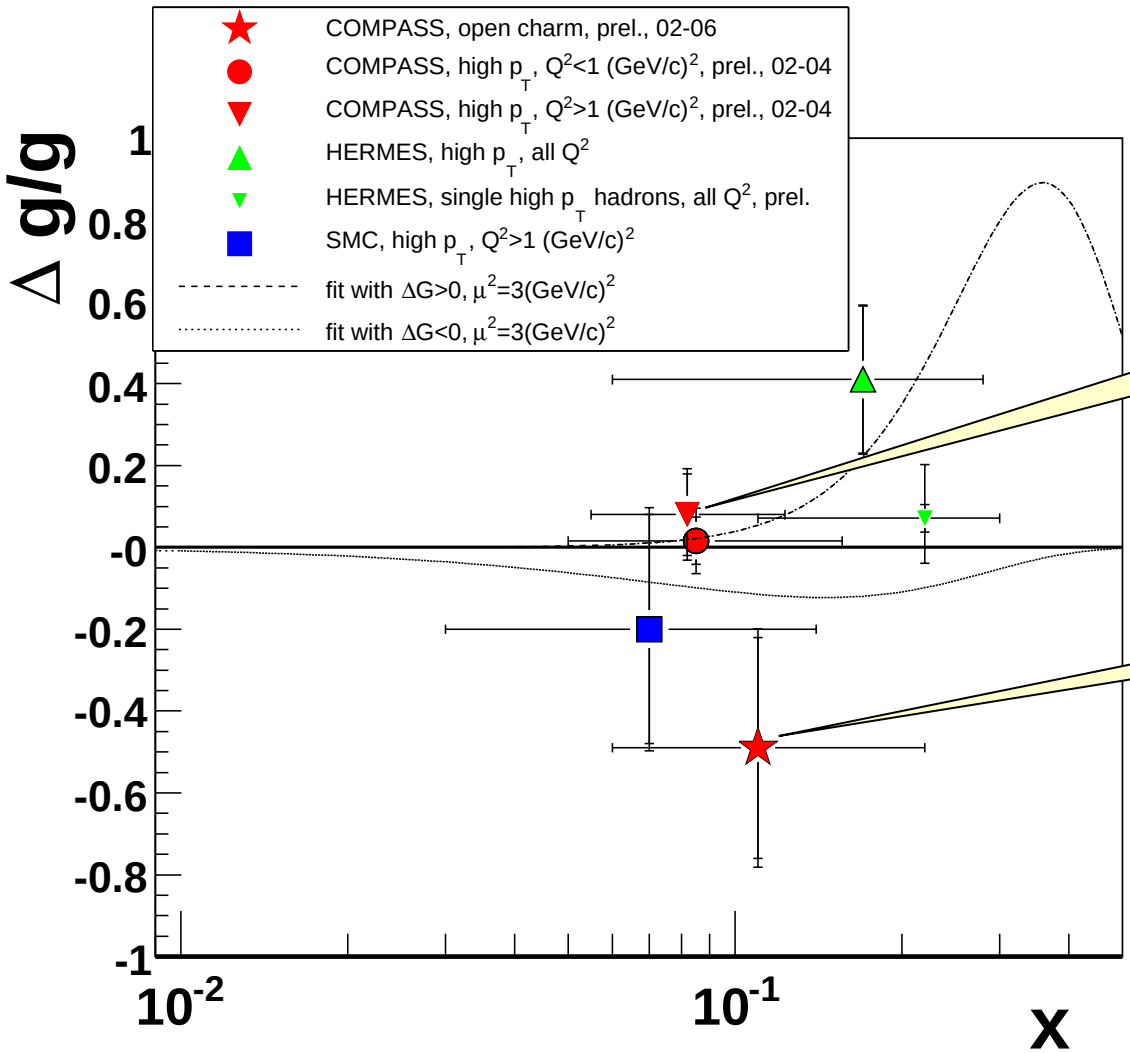


Cuts and asymmetry used for $\Delta G/G$ extraction

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

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

Summary of ΔG/G results



New high-p_T point

See F.Kunne talk

Summary

- New high-p_T analysis has been performed for $Q^2 > 1$ $(GeV/c)^2$
- Preliminary result is:

$$\Delta G/G = 0.08 \pm 0.10 \pm 0.05 \text{ @ } \langle x_G \rangle = 0.082$$

- The new result is in a good agreement with the result from low Q^2 high-p_T analysis

Future:

- 2006 and 2007 data will be included soon (analysis ongoing)
- Significant improvment in the precision is expected
- The split into 2-3 bins in x_G is planned
- Single high-p_T hadron analysis is discussed


October 6 - 11, 2008
University of Virginia, Charlottesville, VA
SPIN 2008
The 18th International Spin Physics Symposium

Thank you