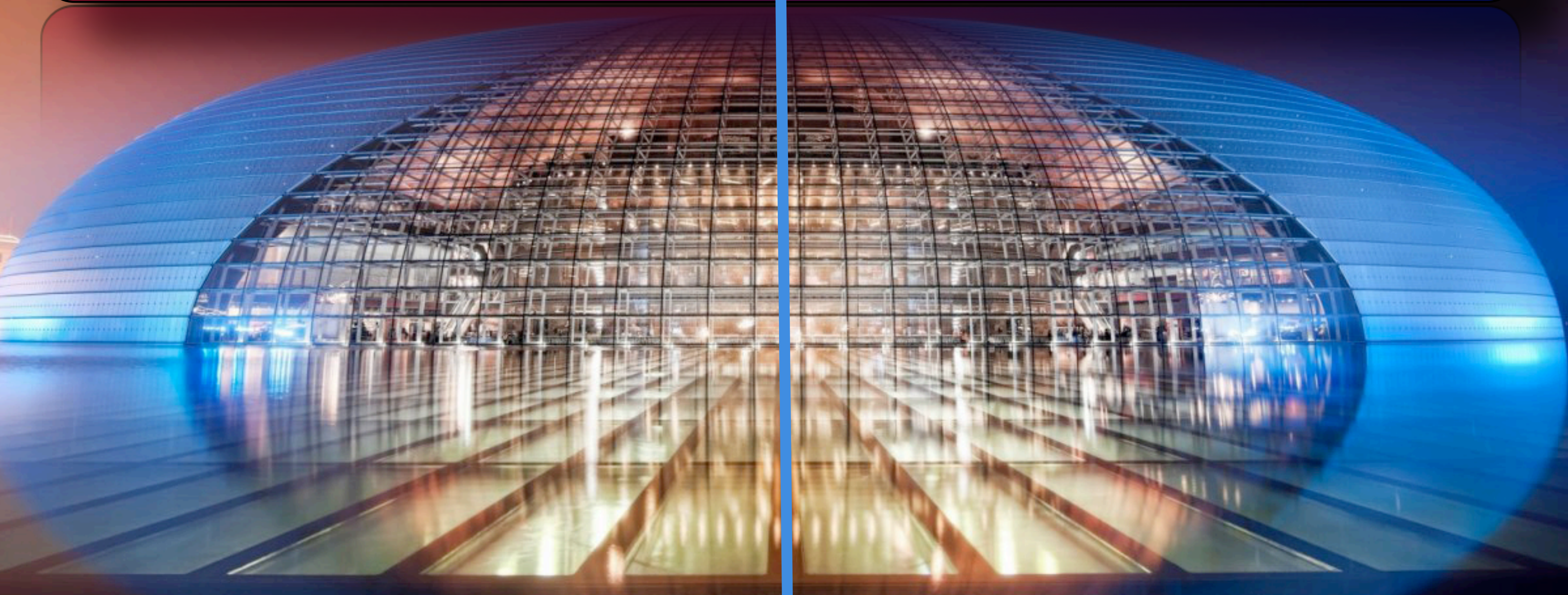
PEKING UNIVERSITY

COMPASS

National Centre for Nuclear Research Warsaw, Poland

Constraints on ΔG from COMPASS data

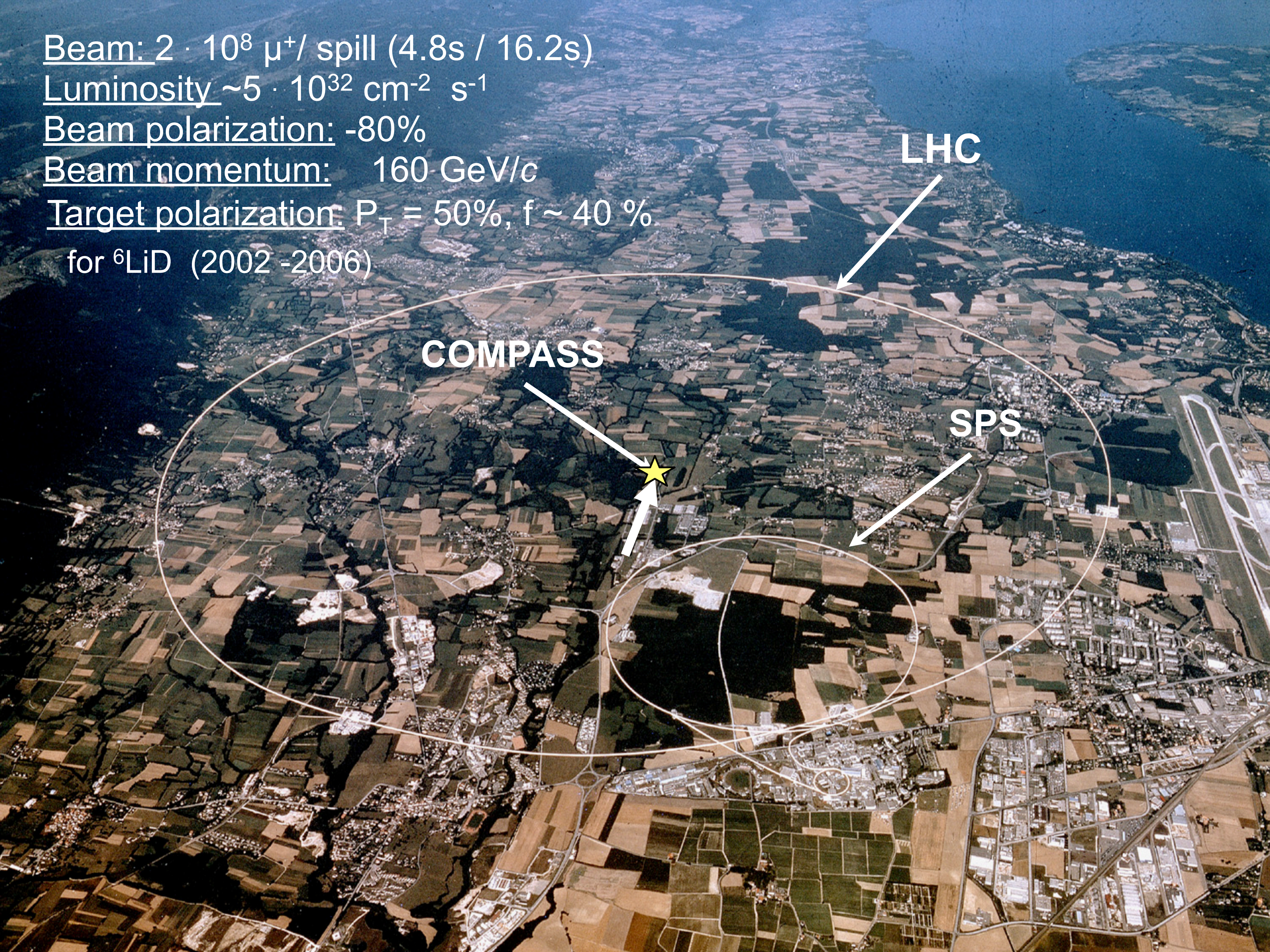
Krzysztof Kurek



Spin2014

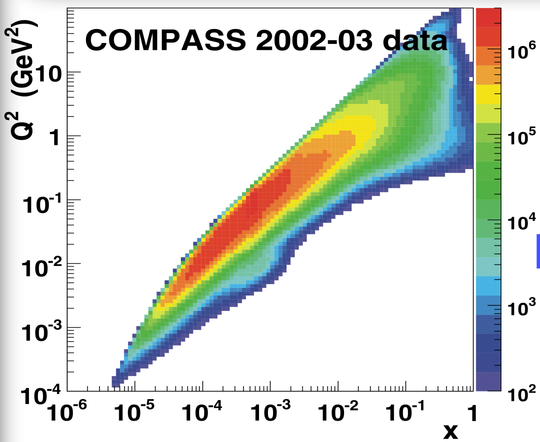
The 21st International Symposium on Spin Physics

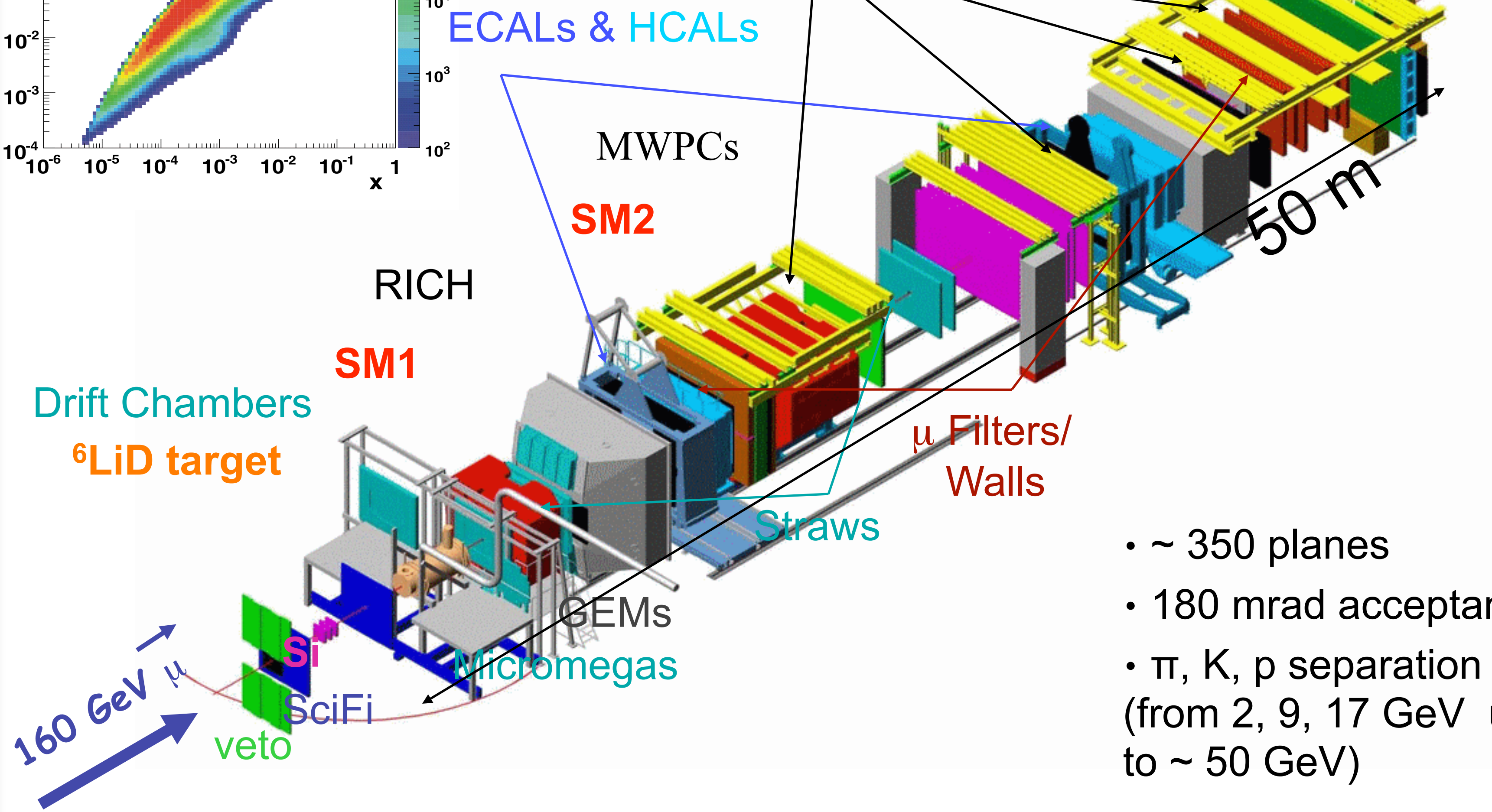
October 20-24, 2014, Beijing, China


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

The COMPASS spectrometer

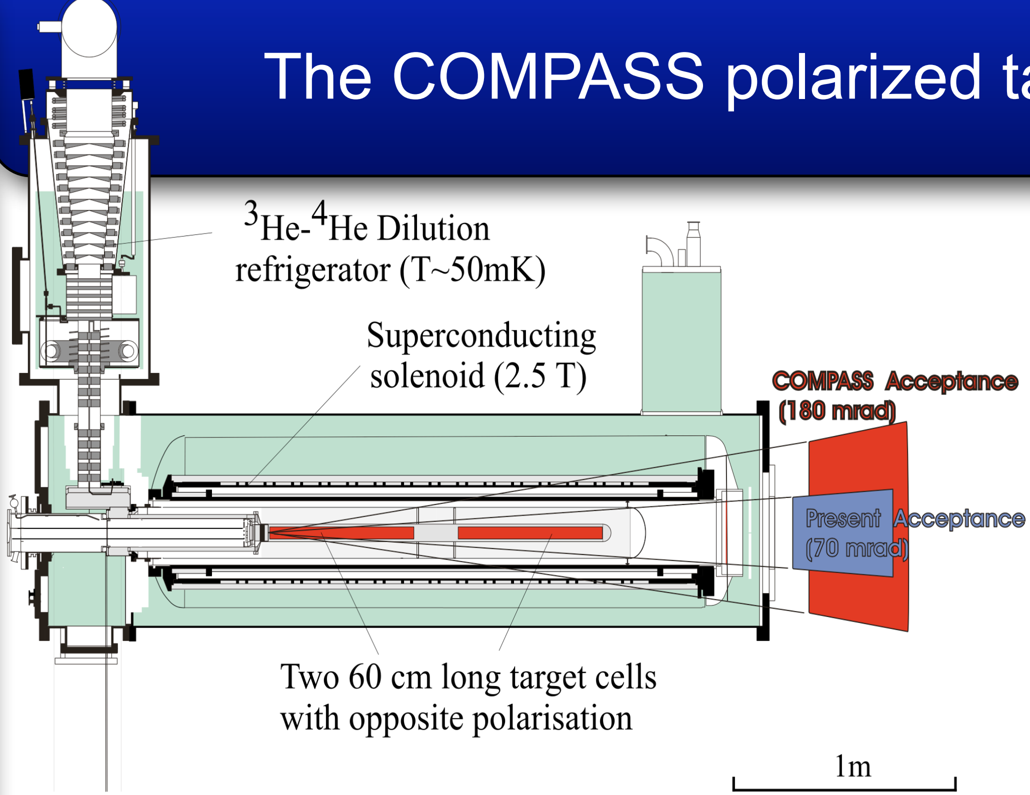
COMPASS in muon run
NIM A 577(2007) 455





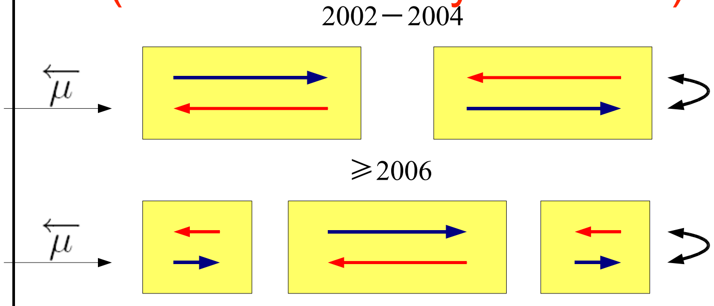
- ~ 350 planes
- 180 mrad acceptance
- π, K, p separation (from 2, 9, 17 GeV up to ~ 50 GeV)

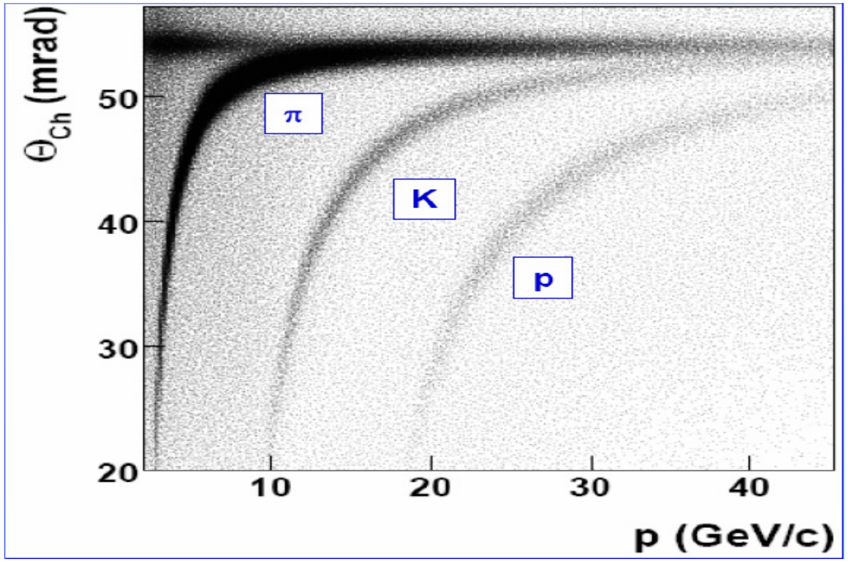
The COMPASS polarized target and PID



Target material: ^{6}LiD
Polarisation: >50%
Dilution factor: ~0.4
Dynamic Nuclear Polarization

2006 - new solenoid
with acceptance 180 mrad
3 target cells
(reduce false asymmetries)





RICH 2006 upgrade : better PID

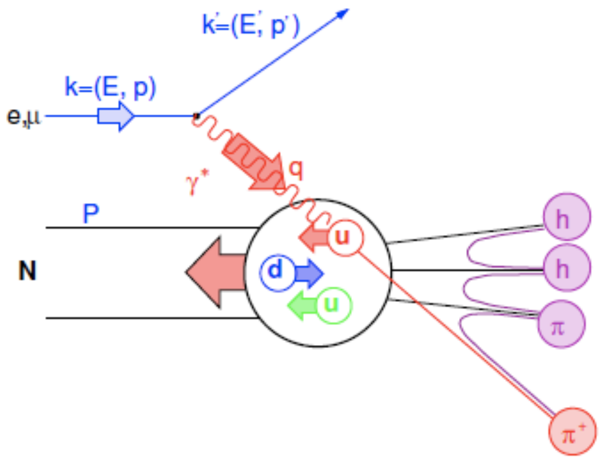
MAPMTs in central region

APV electronics in periphery

Content

- Introduction
- Gluon polarisation measurement @ COMPASS
- High transverse momentum hadron pairs for large and low Q^2
- Artificial Neural Network approach
- Data selection and data and Monte Carlo comparison
- Results
- Determination of gluon polarisation using all−p_T method
- Data selection and data and Monte Carlo comparison
- Results
- Gluon polarisation from COMPASS open-charm data
- D^0 mesons reconstruction and signal to background estimation
- Analyzing power and statistically optimized analysis
- Result for gluon polarisation at NLO QCD approximation
- QCD fits and summary

Basic tool: the measurement of inclusive and semiinclusive asymmetry



Inclusive asymmetry:

$$A_1(x,Q^2)=\frac{\sigma_{\uparrow\downarrow}-\sigma_{\uparrow\uparrow}}{\sigma_{\uparrow\downarrow}+\sigma_{\uparrow\uparrow}}\approx\frac{\sum_q e_q^2\,\Delta q(x,Q^2)}{\sum_q e_q^2\,q(x,Q^2)}=\frac{g_1(x,Q^2)}{F_1(x,Q^2)}$$

$$A_1^h(x,z,Q^2)=\frac{\sigma^h_{\uparrow\downarrow}-\sigma^h_{\uparrow\uparrow}}{\sigma^h_{\uparrow\downarrow}+\sigma^h_{\uparrow\uparrow}}\approx\frac{\sum_q e_q^2\,\Delta q(x,Q^2)D_q^h(z,Q^2)}{\sum_q e_q^2\,q(x,Q^2)D_q^h(z,Q^2)}$$

Semi-inclusive asymmetry:

Compass g_1 results: deuteron/proton 160 GeV — Phys. Lett. B 647 (2007) 8, 330 (low Q^2); Phys. Lett. B 690 (2010) 466

proton 200 GeV — M. Wilfert DIS 2014

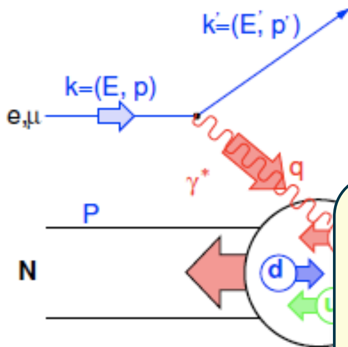
inclusive and semi-inclusive asymmetry measured on proton and neutron or deuteron allows to full flavour separation

Phys. Lett. B 660 (2008) 458
Phys. Lett. B 680 (2009) 217
Phys. Lett. B 693 (2010) 227

Basic tool: the measurement of inclusive and semiinclusive asymmetry

Inclusive asymmetry:

$$A_1(x,Q^2)=\frac{\sigma_{\uparrow\downarrow}-\sigma_{\uparrow\uparrow}}{\sigma_{\uparrow\downarrow}+\sigma_{\uparrow\uparrow}}\approx\frac{\sum_q e_q^2\,\Delta q(x,Q^2)}{\sum_q e_q^2\,q(x,Q^2)}=\frac{g_1(x,Q^2)}{F_1(x,Q^2)}$$



quark contribution to the proton spin: ~ 1/3

COMPASS :from first moment of g_1

Semi-inclusive asymmetry:

Compass g_1 results: deuteron/proton 160 GeV — Phys. Lett. B 647 (2007) 8, 330 (low Q^2); Phys. Lett. B 690 (2010) 466

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Phys. Lett. B 660 (2008) 458
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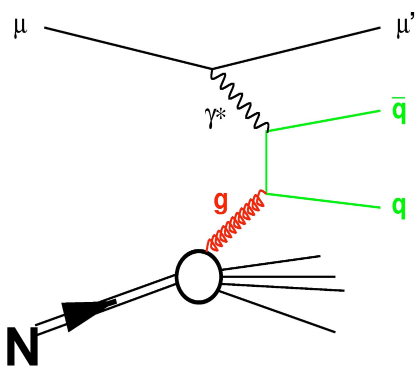
Introduction

Direct gluon polarisation measurement via tagging PGF process

Non direct measurement of gluon polarisation - QCD fits



To select PGF process two methods are used @COMPASS:

- Open-charm D meson production:
  charm quark pairs produced in PGF, "clean" channel however with huge combinatorial background, low statistics but analysis less MC dependent

- High transverse momentum hadron pairs production:
  light quark pairs produced, high statistics but physical background; strongly model and MC dependent analysis, requires a very good agreement between data and MC

$$\sigma^{PGF} = G \otimes \hat{\sigma}^{PGF} \otimes H$$

$$\Delta\sigma^{PGF} = \Delta G \otimes \Delta\hat{\sigma}^{PGF} \otimes H$$

from MC

$$A \approx \frac{\Delta G}{G}(\bar{x}_G) < \hat{a}_{LL}^{PGF} >_G$$

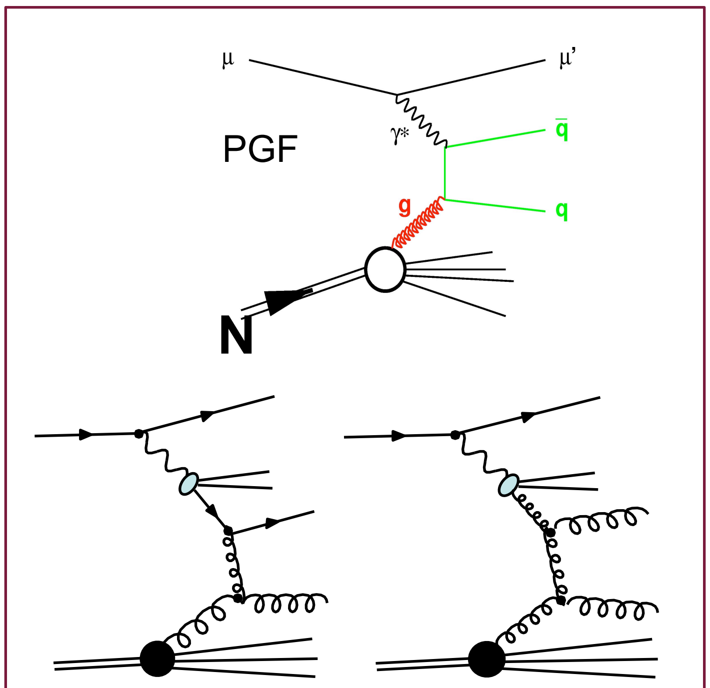
signal asymmetry from data

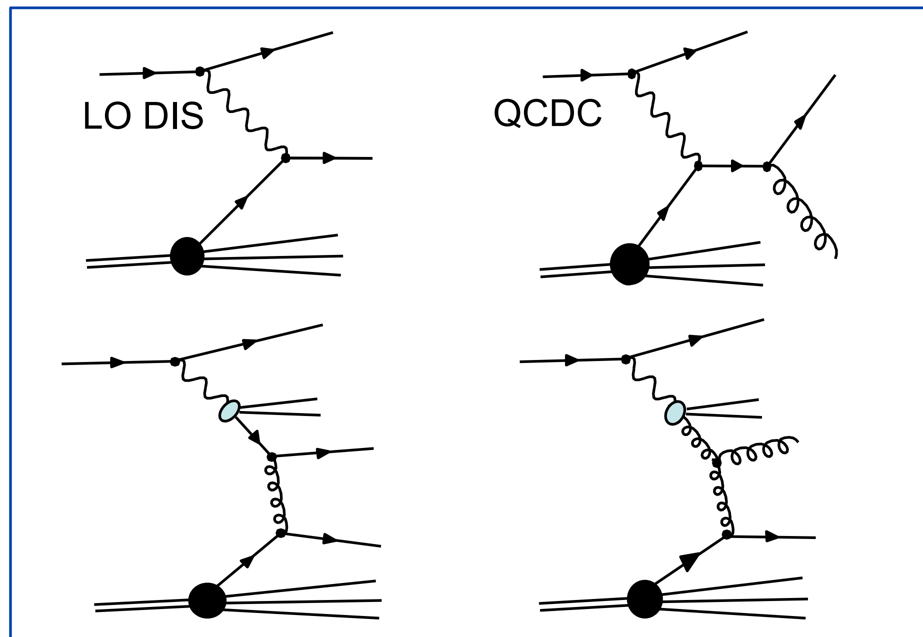
Low Q^2 & large Q^2 : Q2< 1 & Q^2 >1 $(GeV/c)^2$

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

Two kinematical regions: low and large Q^2

- low Q^2 - here p_T is a perturbative scale, also resolved photon contribution important (~50%)
- large Q^2 - scale Q^2 , method based on Neural Network approach used

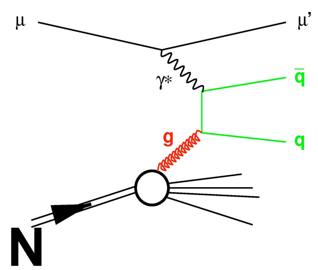




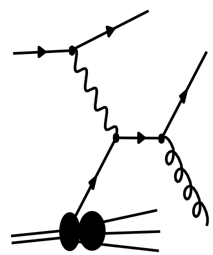
COMPASS@Low Q^2 - Phys. Lett. B 633 (2006) 25

Large Q^2 : $Q^2 > 1\ (GeV/c)^2$

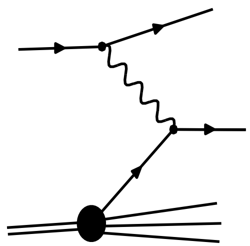
Physical model: three processes (LO QCD)



PGF



QCD-Compton



LO-DIS

$$A_{LL}^{2h}(x_{Bj}) \approx \frac{\Delta G}{G}(x_G)\hat{a}_{LL}^{PGF}R_{PGF} + A_1^{LO}(x_C)\hat{a}_{LL}^{C}R_C + A_1^{LO}(x_{Bj})DR_L$$

$$A_1^{LO} \equiv \frac{\sum_i e_i^2 \Delta q_i}{\sum_i e_i^2 q_i}$$

Same decomposition for inclusive sample to determine A_1^{LO}

Optimization needed : “clean” (more PGF, “pure”) sample with limited statistics or less PGF populated but larger sample

Master formula for determination ΔG
Data selection

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

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

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

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

a_{LL} are so-called analyzing powers
D is a depolarization factor.

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

Data selection:

- Interaction vertex with an incoming and an outgoing muons
- $Q^2 > 1\ (\mathrm{GeV}/c)^2$ and $0.1<y<0.9$ (inclusive sample)
- Events with at least 2 hadrons in the final state (2h sample)
- The hadrons which form the high-p_T pair:

$p_{T1} > 0.7$ GeV/c $p_{T2} > 0.4$ GeV/c
$z_1 + z_2 < 0.95$

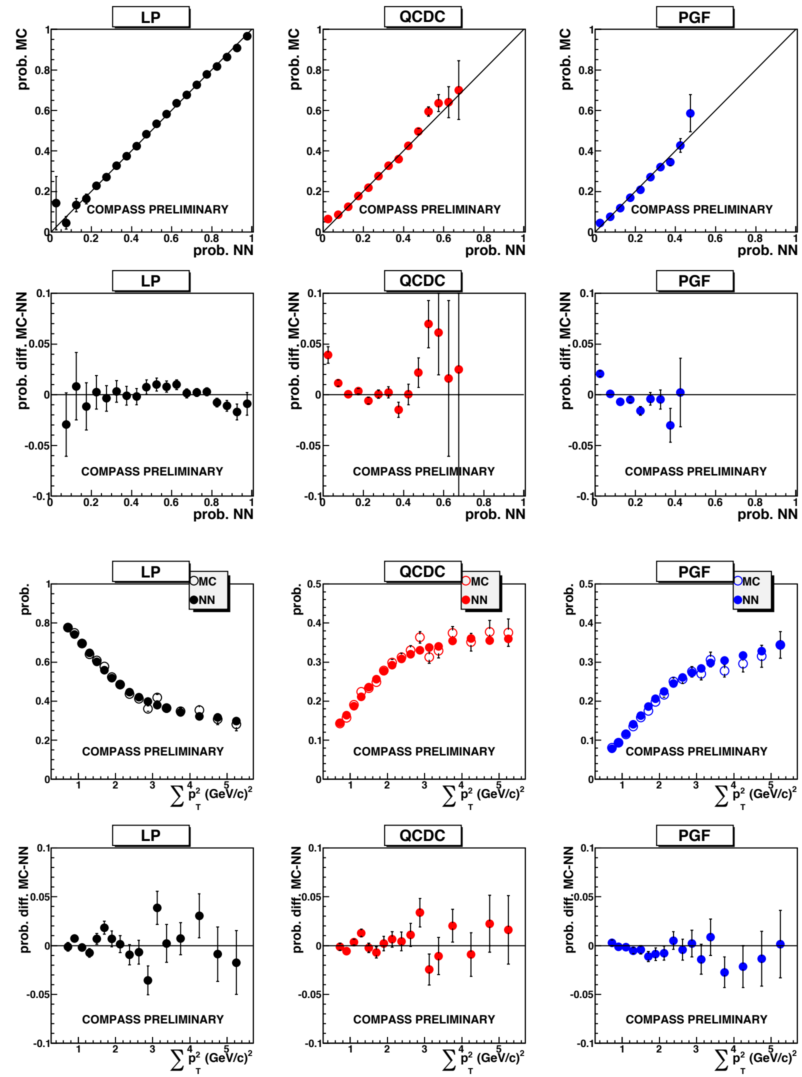
these cuts define high-p_T sample; 2002-2006 data: ~7.3 M events

Event-by-event basis weighted method
Artificial Neural Network approach

The following factors must be known 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
- Remaining factors have to be obtained from MC
- ANN trained on MC samples, then used on real data
- Input variables for ANN trainning:
  - 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

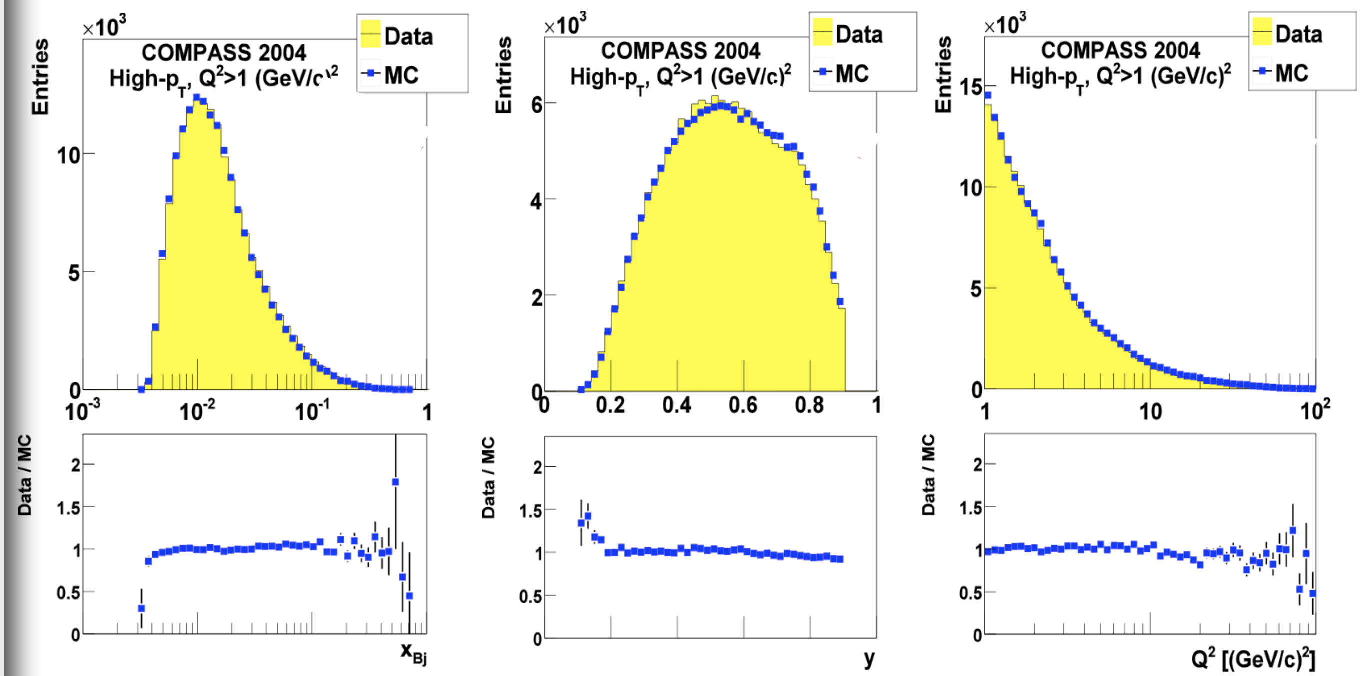


MC vs Data (sample: 2004)

Data selection and MC comparison

Two types of MC samples have been used:
- inclusive one
- high-p_T

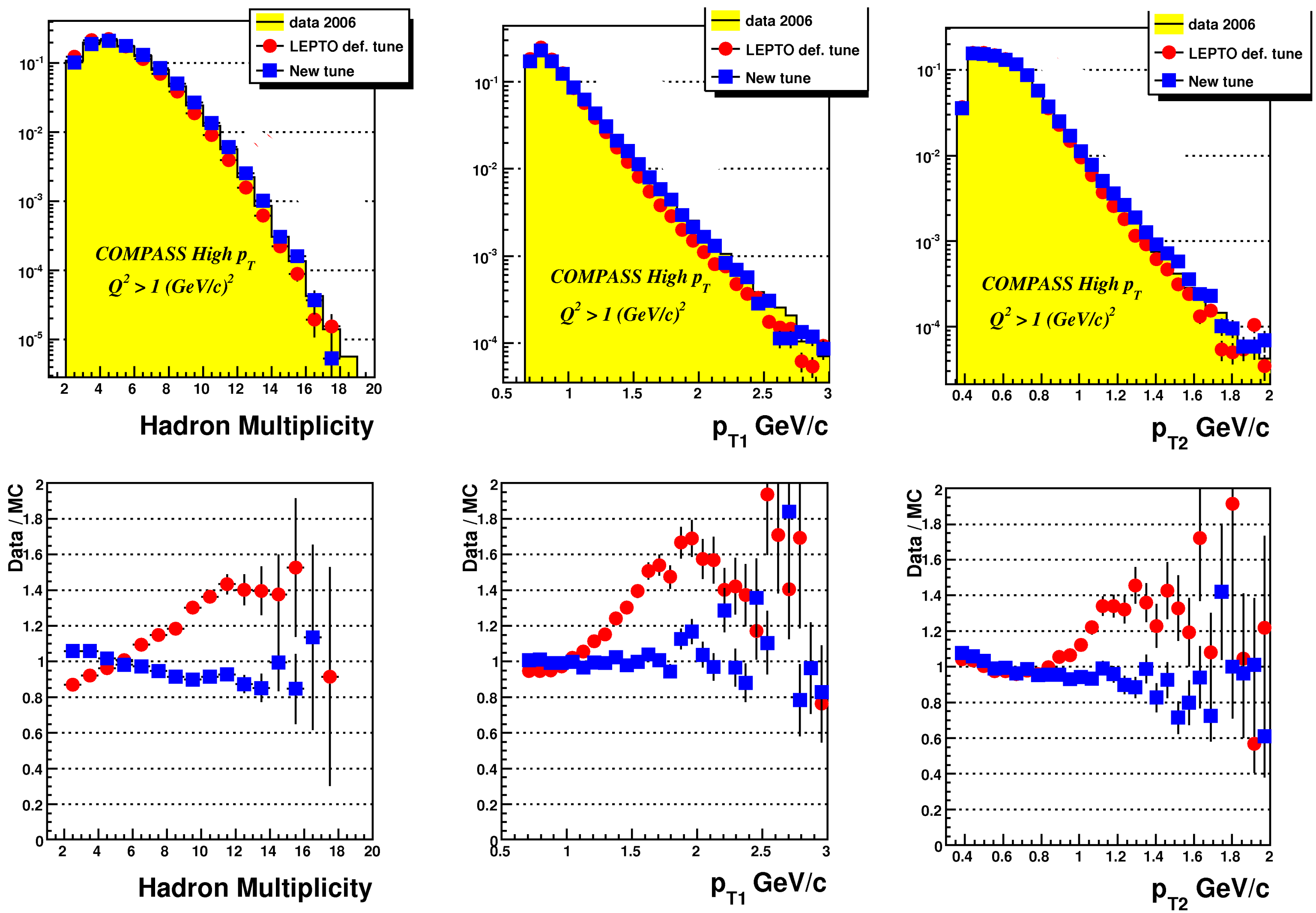
Full chain of MC simulation:
LEPTO+JETSET + GEANT + Reconstruction
- PDF - MSTW2008LO
- high-p_T sample:
  - MC tuning to improve hadron production description: shapes (momenta) and multiplicity (fragmentation)



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

MC vs Data (sample: 2006)

effect of tuning clearly visible



Systematic studies & results

- Neural Network stability
- MC
- False Asymmetries
- $\delta P_b, \delta P_t, \delta f$
- A_1 parametrisation
- Simplification of the Formula for ΔG/G

$\delta(\Delta G/G)_{NN}$	0.010
$\delta(\Delta G/G)_{MC}$	0.045
$\delta(\Delta G/G)_{false}$	0.019
$\delta(\Delta G/G)_{f,Pb,Pt}$	0.004
$\delta(\Delta G/G)_{A1}$	0.015
$\delta(\Delta G/G)_{formula}$	0.035
Total	0.063

$$\frac{\Delta G}{G} = 0.125 \pm 0.060 \pm 0.063$$

$$x_G = 0.09^{+0.08}_{-0.04} \qquad \langle \mu^2 \rangle = 3 \quad (GeV/c)^2$$

	1st point	2nd point	3rd point
ΔG/G	0.15 ± 0.09 ± 0.09	0.08 ± 0.10 ± 0.08	0.19 ± 0.17 ± 0.14
$\langle x_g \rangle$	$0.07^{+0.05}_{-0.03}$	$0.10^{+0.07}_{-0.04}$	$0.17^{+0.10}_{-0.06}$

Phys. Lett. B 718 (2013) 922

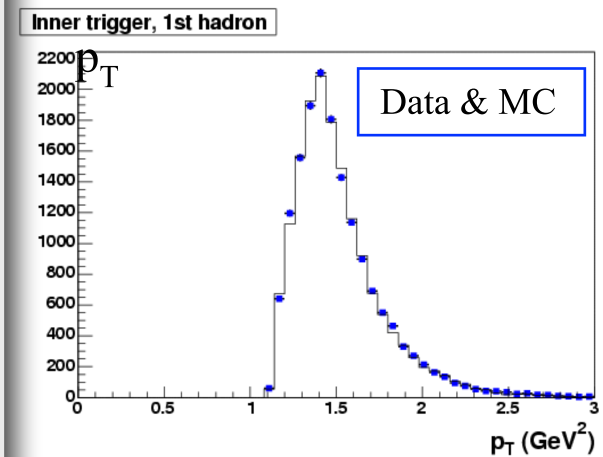
These 3 points show no x_G dependence (within errors)

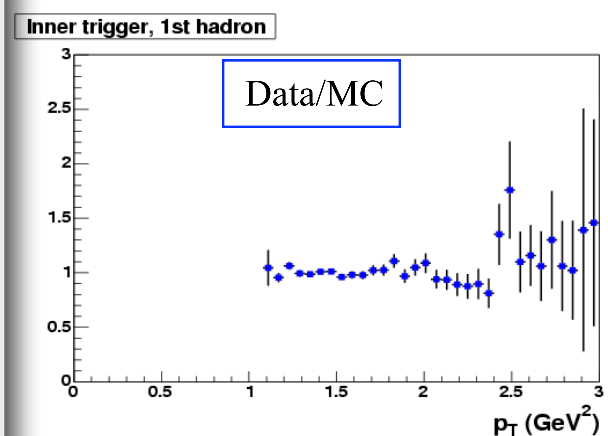
Results for low Q^2 : $Q^2 < 1\ (GeV/c)^2$

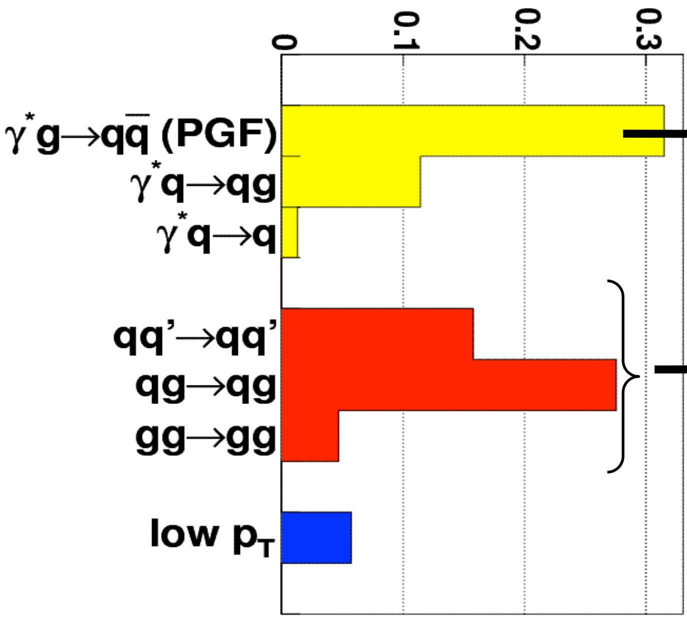
Cuts used – cut on $\Sigma p_T^2 > 2.5\ (GeV/c)^2$

90% of statistics!

PYTHIA generator for low Q^2 + spectrometer simulation







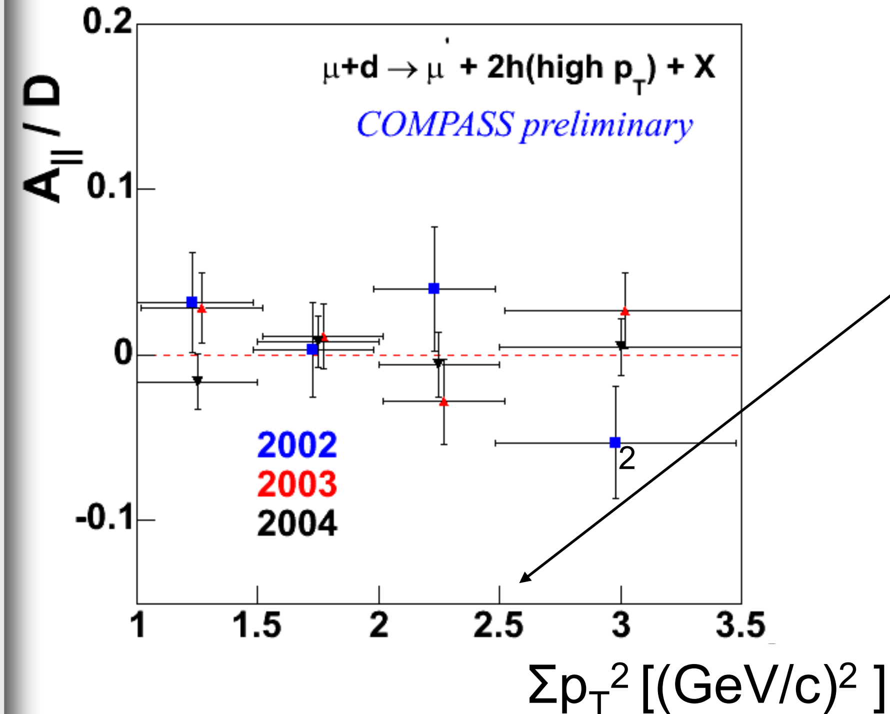
$R_{PGF} \approx 30\%$

$R_{Res.Phot} \approx 50\%$

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

Results for low Q^2 : $Q^2 < 1$ $(GeV/c)^2$

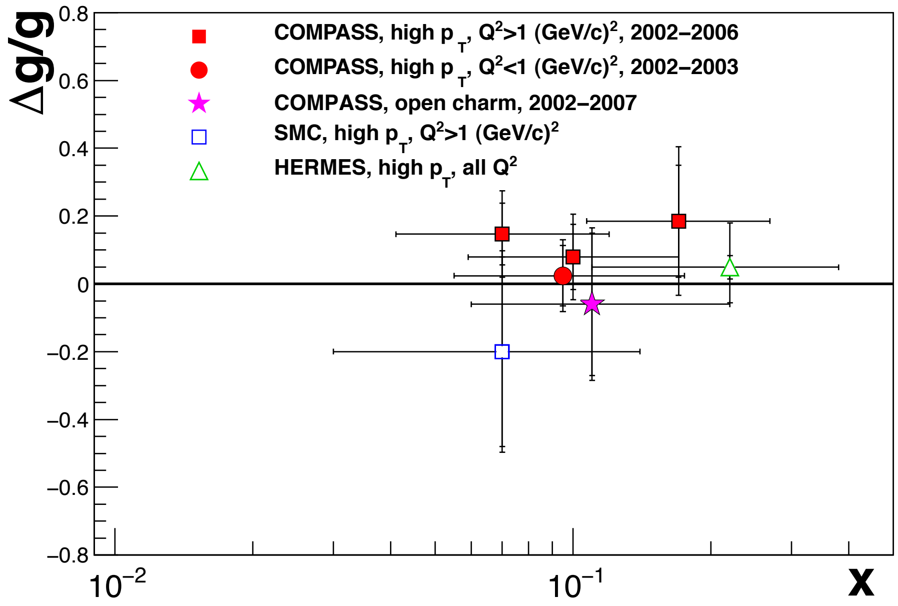
2002-03 results published: Phys. Lett. B 633 (2006) 25



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

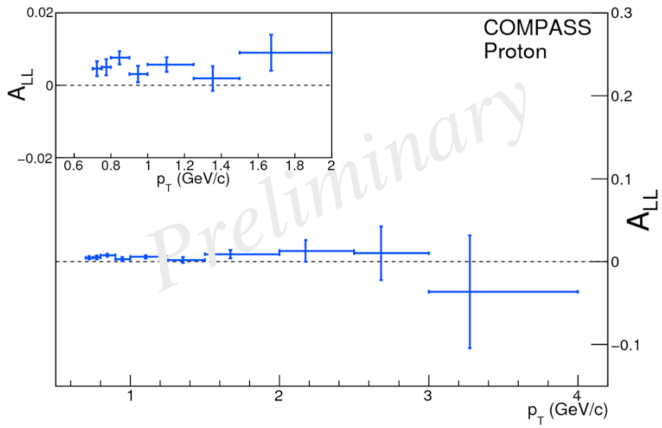
Data	$(\Delta G/G)(x_g)$	stat	exp.syst	MC.syst	resolved photon
02-03	0.024	0.089	0.014	0.052	0.018
02-04	0.016	0.058	0.014	0.052	0.013

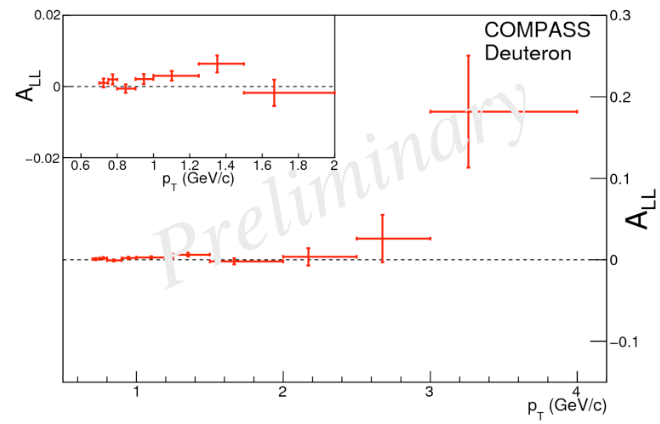
Results for low & large Q^2



Preliminary results on asymmetries for low Q^2

more details:
DIS 2014: M. Levillain
A. Nunes





NLO calculations for low Q^2

M. Stratmann, B Jager, W. Vogelsang EPJC 44(2005) 533
COMPASS: potentially discriminated power on gluon polarisation

Unpolarised cross-section - comparison with calculations:
COMPASS: Phys. Rev. D88 (2013) 091101,
Comparison: Phys. Rev. D88 (2013) 014024

New analysis - all-p_T methods

M. Stolarski DIS 2014, paper in preparation

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

Problem in A_1^{LO} - unknown

Can be calculated from polarised PDFs but:
- @ LO - biased results & error
- @ NLO - inconsistent with LO analysis, contains also Δg

In the previous analysis - taken from inclusive data: A_1^d
Phys. Lett. B 718 (2013) 922
price: complicated formula + large systematics

New method: extract A_1^{LO} simultaneously with $\Delta g/g$

J.Pretz, J-M Le Goff NIM A 602 (2009) 594
COMPASS open-charm: Phys. Rev. D (2013) 052018

New analysis - all-p_T methods

To optimize statistical error - a „clean" source of PGF and QCDC processes as well as LO processes needed;

- PGF/QCDC - high-p_T data
- LO - low-p_T data

data without p_T cut used! increase statistics (~100 M)

Some of the systematics uncertainty reduced:

- no error related to the „master" formula
- no A_1^d parameterization needed
- reduced experimental false asymmetries

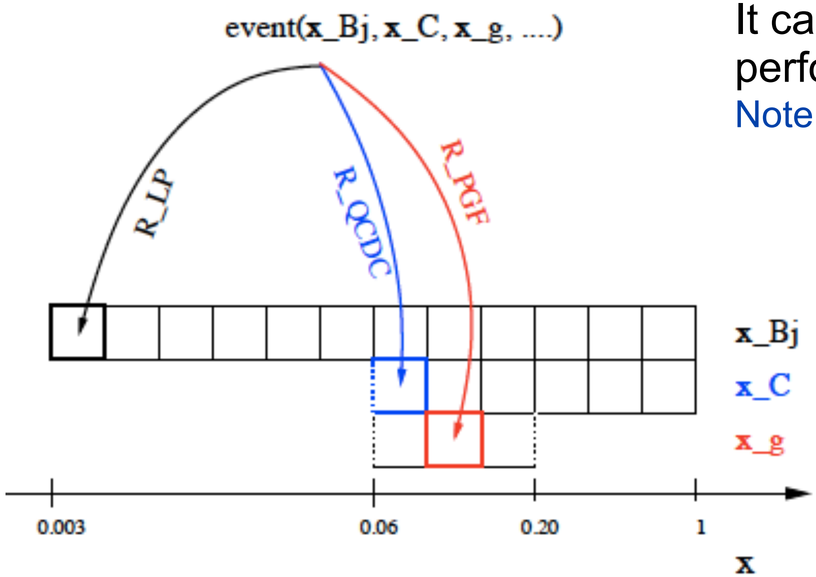
the statistical weight simpler than in previous analysis

- $w_{new} \sim a_{LL}^{PGF} R_{PGF}$
- $w_{old} \sim a_{LL}^{PGF} R_{PGF} - a_{LL}^{incl,PGF} R_{PGF}^{incl} \left(\frac{R_{LP} + R_{QCDC} a_{LL}^{QCDC} / D}{R_{LP}^{incl}} \right)$ (~β)

Statistical error on gluon polarisation reduced - higher statistics

New analysis - all-p_T method
A_1 compatibility check

$$A_1^{QCDC}(x_C) = A_1^{LP}(x_{Bj}) = A_1^{LO}(x);\ \text{for } x_C = x_{Bj}$$



It can be verified equality of the two asymmetries by performing χ^2 test and select the best MC tuning ;
Note that statistical weight is constructed on the MC basis

	name	χ^2
1	HIPT_PSON_MS_FLUKA	8.1
2	HIPT_PSON_MS	8.8
3	HIPT_PSOFF_MS	3.9
4	HIPT_PSON_CQ	10.1
5	HIPT_PSON_MS_NOFL	6.9
6	DEF_PSON_CQ	13.1
7	DEF_PSON_MS	10.7
8	DEF_PSOFF_MS	9.9

Data selection:
standard DIS cut on inclusive variables (large Q^2)
at least one charged hadron detected - no high-p_T cut !
for ANN information from one, leading hadron only is used

New analysis - all-p_T method results

As in the previous analysis ANN is used - now only four variables: x_{Bj}, Q^2, p_T and p_L are used for training

Minimalization procedure and covariant matrix is used for error estimation;

simultaneously A_1^{LO} and $\Delta g/g$ is fitted.

$$\Delta g/g = 0.113 \pm 0.038 \pm 0.035 \quad \text{(Preliminary)}$$

- the scale, $\mu^2 = < Q^2 > \approx 3\ (\text{GeV}/c)^2$, and $< x_g > \approx 0.10$
- the result obtained under the assumption: $A_1^{QCDC}(x_C) = A_1^{LP}(x_{Bj})$ for $x_C = x_{Bj}$

comparing to

$$\frac{\Delta G}{G} = 0.125 \pm 0.060 \pm 0.063$$

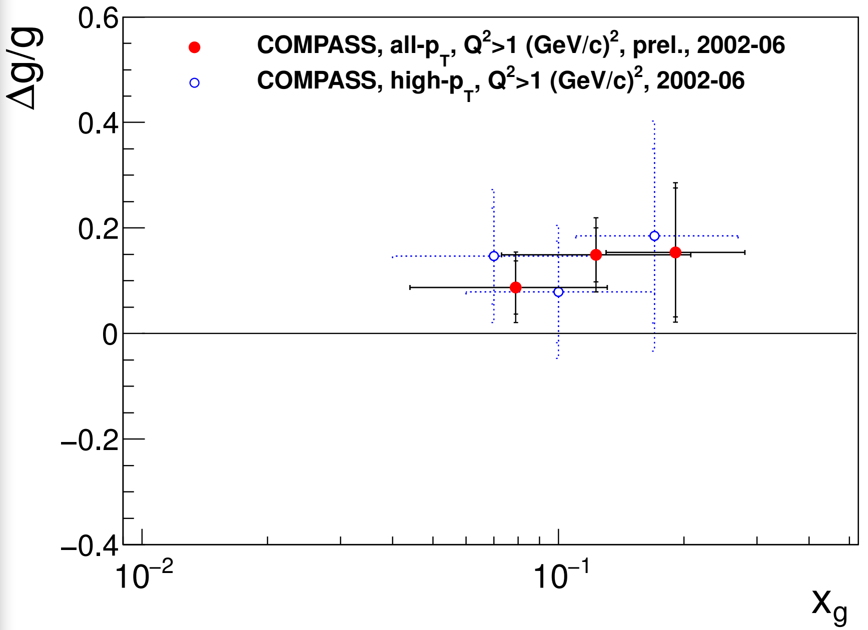
$$x_G = 0.09^{+0.08}_{-0.04} \qquad \langle \mu^2 \rangle = 3.4 (GeV/c)^2$$

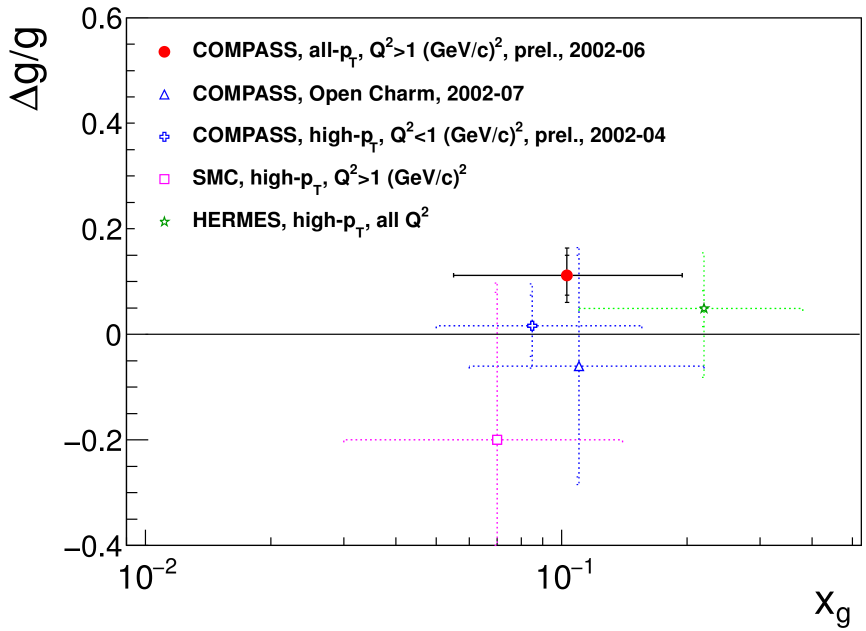
significantly reduced statistical and systematics

New analysis - all-p_T method results

$\Delta g/g$ has been obtained in three x_g bins

Good agreement with previously published results





Systematic studies mostly same as in previous analysis

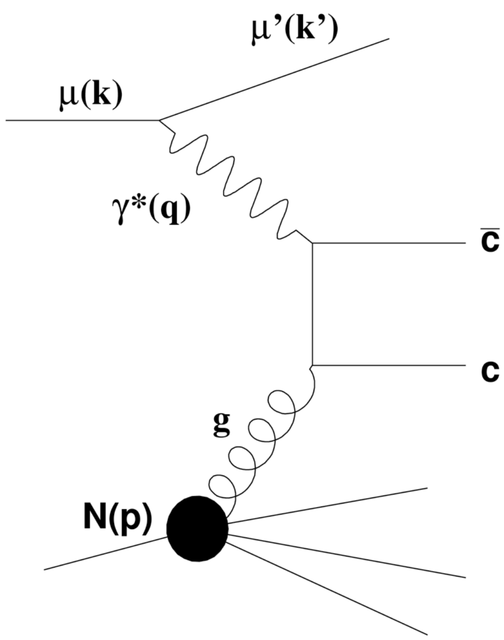
- errors from formula and A_1 are eliminated
- Significantly reduced error from MC: 0.017 vs 0.045
- slightly higher false asymmetries observed (0.029 vs 0.019, correctly taken p_T dependence)

Total: 0.035

D^0 meson production

Low statistics! Huge combinatorial background to fight with!

Phys. Lett. B 676 (2009) 31
Phys.Rev. D 87 (2013) 052018



Open-charm production@COMPASS -
Photon-Gluon Fusion (PGF) - the only process in LO QCD.

$$\sigma^{PGF} = G \otimes \hat{\sigma}^{PGF} \otimes H$$

$$\Delta\sigma^{PGF} = \Delta G \otimes \Delta\hat{\sigma}^{PGF} \otimes H$$

assumption: $$\frac{\Delta G}{G}(x) \approx a(x - \bar{x}) + b$$

from MC

$$A \approx \frac{\Delta G}{G}(\bar{x}_G) < \hat{a}_{LL}^{PGF} >_G$$

signal asymmetry from data

notice:

$$A^{measured} = f P_T P_b \left(\frac{S}{S+B} A^{signal} + \frac{B}{S+B} A^{B} \right)$$

The method similar to all-p_T

Total number of events:

$$\frac{\mathrm{d}^k N}{\mathrm{d}m\,\mathrm{d}X} = a\phi n(s+b)\left[1 + P_t P_\mu f\left(\frac{s}{s+b}A^{\mu N\to\mu' D^0 X} + \frac{b}{s+b}A_B\right)\right].$$

two weights:

$$w_S = P_\mu f D \frac{s}{s+b},$$
$$w_B = P_\mu f D \frac{b}{s+b}.$$

Every event is weighted by these weights and asymmetries for signal and background in $(p_T^{D^0}, E_{D^0})$ intervals are simultaneously extracted.
Gluon polarisation from signal asymmetry is then estimated.

Another way: extract gluon polarisation directly event-by event basis using weights with analyzing power:

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

Statistically optimised determination of gluon polarisation;
takes into account anticorrelation between analyzing power and signal strength

D^0 meson data selection

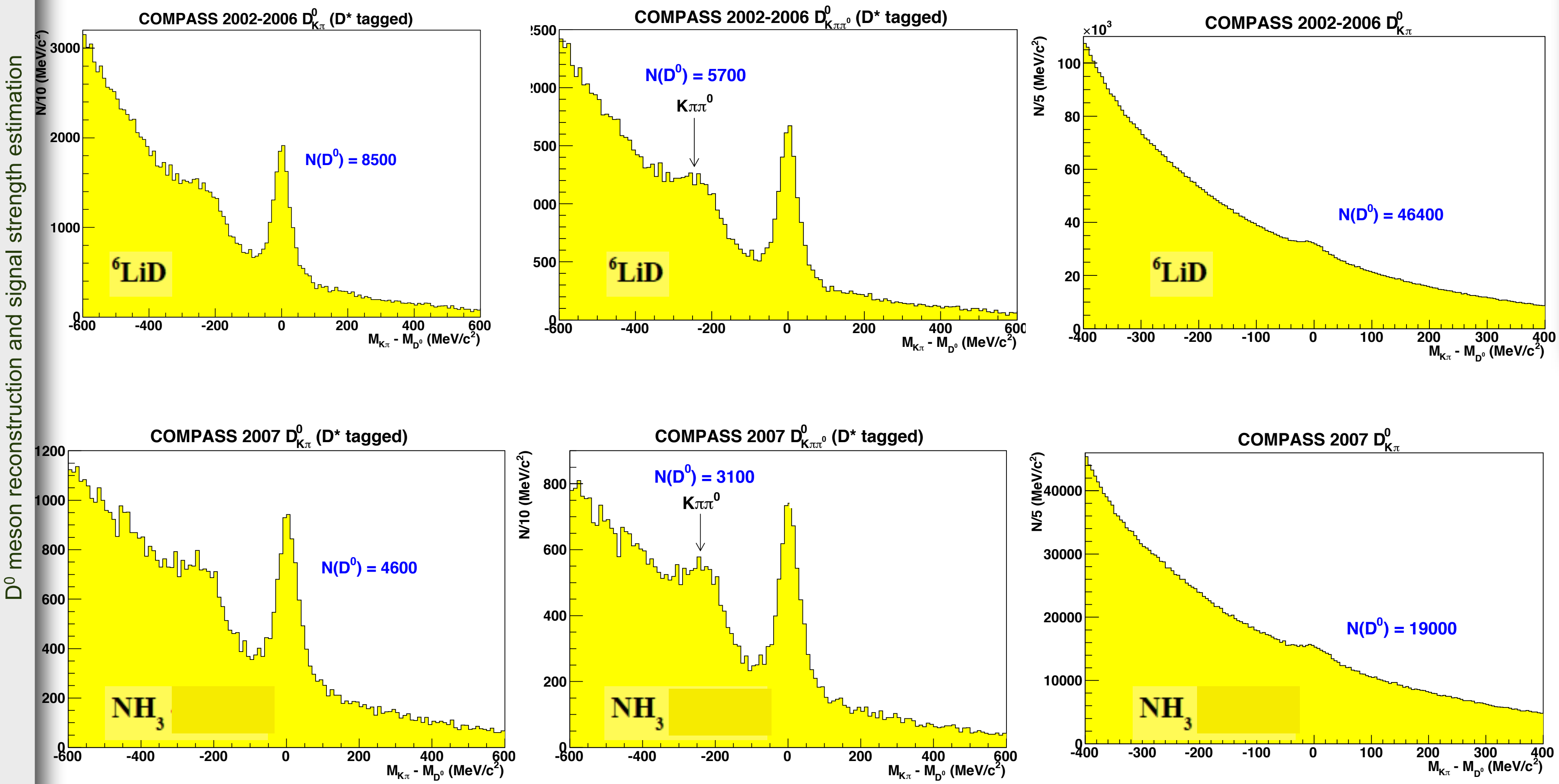
Considered events:

- $D^0 \rightarrow K\pi$ *(BR: 4%)*
- $D^* \rightarrow D^0\pi_s$ *(30% D^0 tagged with a D^*)*
  - $D^0 \rightarrow K\pi$
  - $D^0 \rightarrow K\pi\pi^0$ *(BR: 13%)* → **not directly reconstructed** π^0
  - $D^0 \rightarrow K\pi\pi\pi$ *(BR: 7.5%)*
  - $D^0 \rightarrow sub(K)\pi$ → **no RICH ID for Kaons** *($p < 9$ GeV/c)*

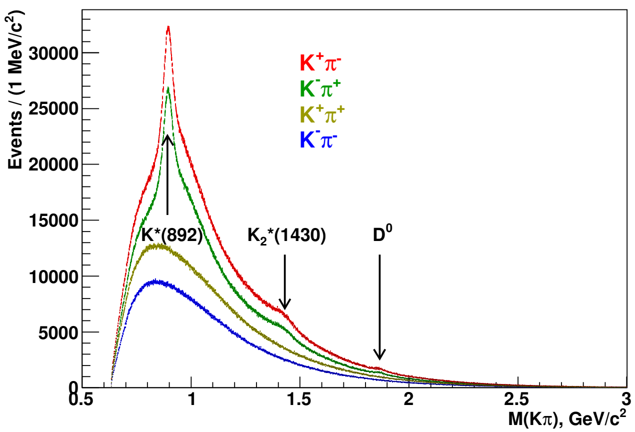
Selection to reduce the combinatorial background

- **Kinematical cuts:** z_D and D^0 decay angle *(to reject colinear events with γ^* coming from the nucleon fragmentation)*, K and π momentum
- **RICH identification:** K and π ID + electrons rejected from the π_s sample
- Mass cut for the D^* tagged channels *($M[K\pi\pi_s] - M[K\pi] - M[\pi]$)*
- Neural Network qualification of events

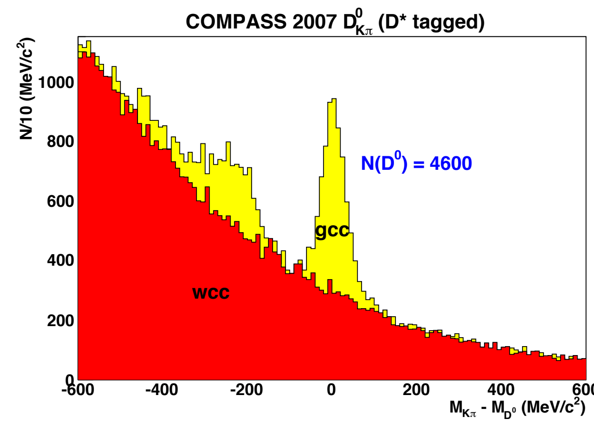
D^0 meson reconstruction



Artificial Neutral Network qualification of events

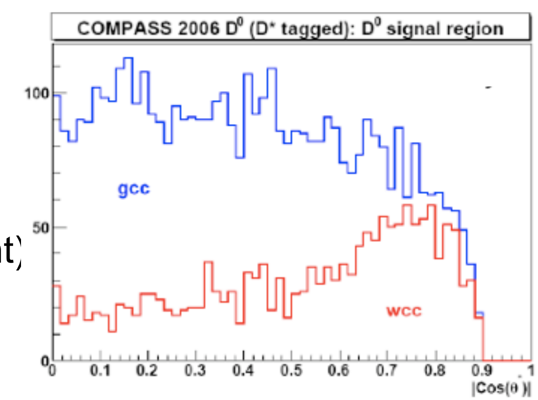


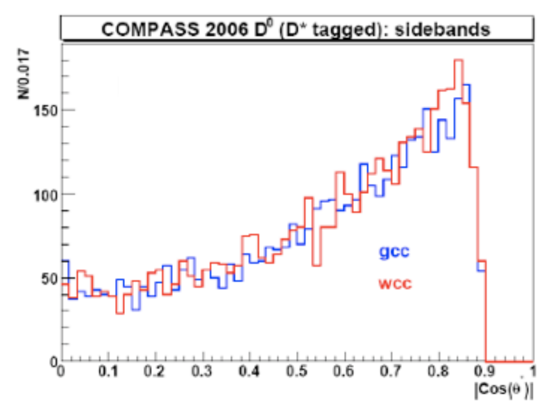
gcc: signal+background
wcc: pure background



- Assuming background model to be good *Neural Network* is able to find some differences between samples: *S+B* and *B*.
- This way the signal probability *S/(S+B)* is constructed event-by-event

An example of “good” training variable in signal region (left) and for sidebands (right)





Gluon polarization

Final gluon polarization result from open-charm in LO QCD

$$\left\langle \frac{\Delta g}{g} \right\rangle = -0.10 \pm 0.22\ (\text{stat.}) \pm 0.09\ (\text{syst.})$$

$$\left\langle \frac{\Delta g}{g} \right\rangle = -0.06 \pm 0.21\ (\text{stat.}) \pm 0.08\ (\text{syst.})$$

from asymmetries $\langle x_G \rangle = 0.11^{+0.11}_{-0.05}$ $\mu^2 \approx 13 \frac{GeV^2}{c^2}$ Statistically optimised

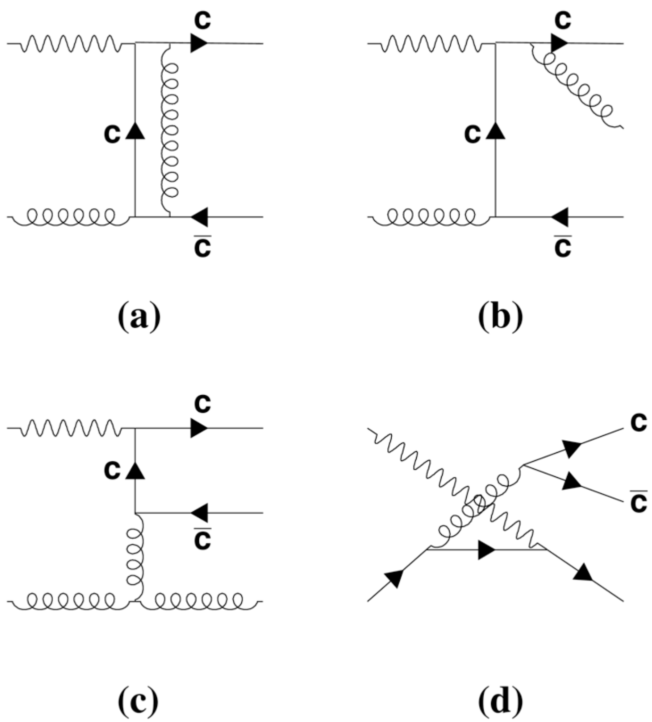
Source	$\delta(\langle \Delta g/g \rangle)$	Source	$\delta(\langle \Delta g/g \rangle)$
Beam polarisation P_μ	0.005	$s/(s+b)$	0.007
Target polarisation P_t	0.005	False asymmetry	0.080
Dilution factor f	0.002	a_{LL}	0.015
Assumption, Eq. (9)	0.025	Depolarisation factor D	0.002
Total uncertainty	0.086		

Source	$\delta(\langle \Delta g/g \rangle)$	Source	$\delta(\langle \Delta g/g \rangle)$
Beam polarisation P_μ	0.003	$s/(s+b)$	0.004
Target polarisation P_t	0.003	a_{LL}	0.005
Dilution factor f	0.001	False asymmetry	0.080
Assumption, Eq. (9)	0.025		
Total uncertainty	0.084		

More details and asymmetries in bins - see:
Phys.Rev. D 87 (2013) 052018

Gluon polarisation @ NLO QCD

I.Bojak, M.Stratmann, Nucl.Phys.B 540 (1999) 345, I.Bojak, PhD th.
J.Smith, W.L.Neerven, Nucl.Phys.B 374 (1992)36),
W.Beenakker, H.Kuijf, W.L.Neerven,,J.Smith, Phys.Rev.D40(1989)54



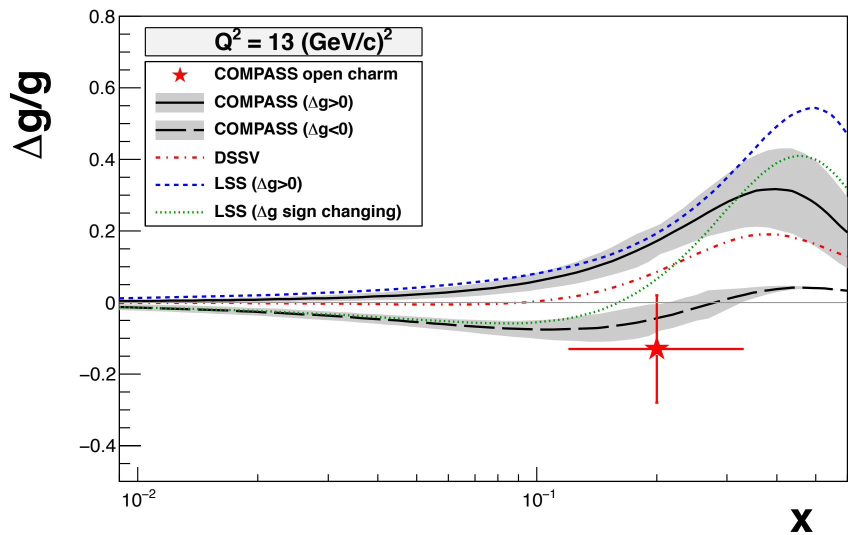
Procedure for NLO calculations:

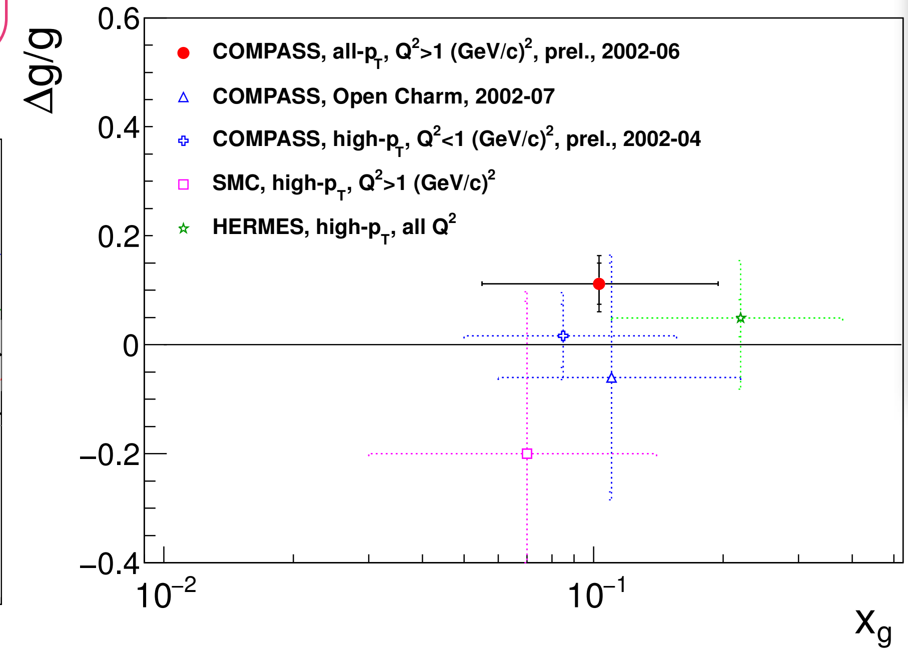
1. *Aroma* MC generator with Parton Shower-on describes COMPASS data very well
2. PS simulates phase space for NLO correction - a_{LL} can be calculated event-by-event basis from theoretical formulas (as in LO case)
3. light quark correction ~ A_1 which is taken directly from data *)
4. Asymmetries in bins used (rebinned in $p_T^{D^0}$ bins only)

Result on gluon polarisation @LO & NLO QCD

Phys.Rev. D 87 (2013) 052018

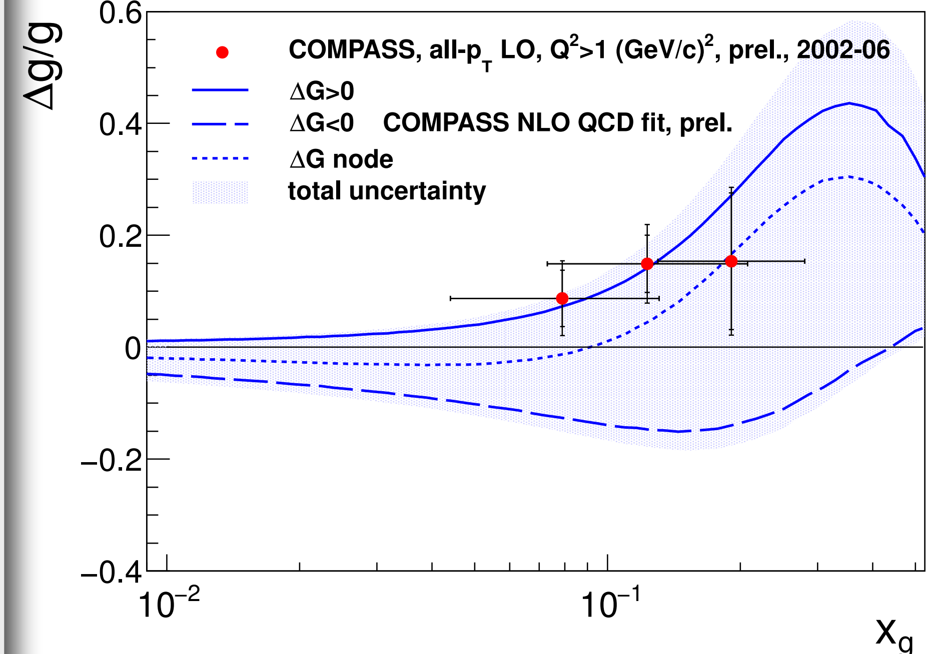
$$\left\langle \frac{\Delta g}{g} \right\rangle^{\mathrm{NLO}} = -0.13 \pm 0.15 \ (\mathrm{stat.}) \pm 0.15 \ (\mathrm{syst.})$$

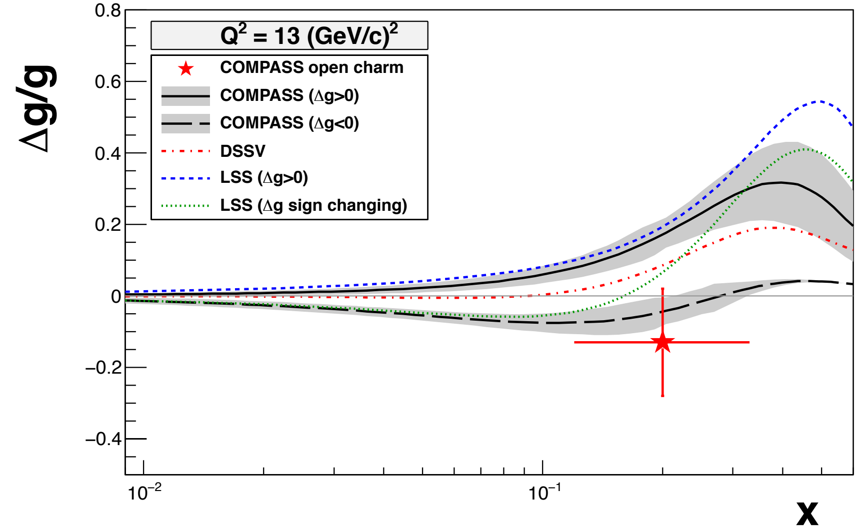




Source	$\delta(\langle \Delta g/g \rangle)$	Source	$\delta(\langle \Delta g/g \rangle)$
Beam polarisation P_μ	0.006	$s/(s+b)$	0.009
Target polarisation P_t	0.006	a_{LL}	0.119
Dilution factor f	0.003	False asymmetry	0.080
Assumption, Eq. (9)	0.025	Depolarisation factor D	0.002
Total uncertainty 0.146			

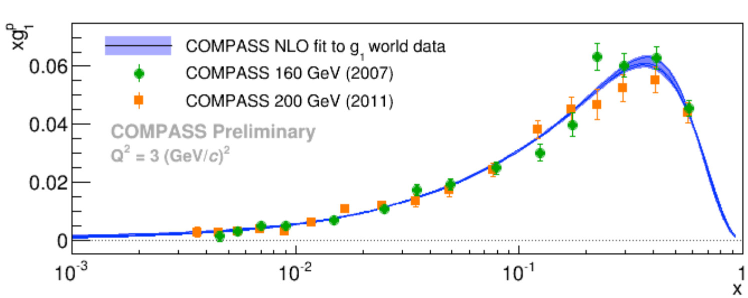
COMPASS QCD analysis

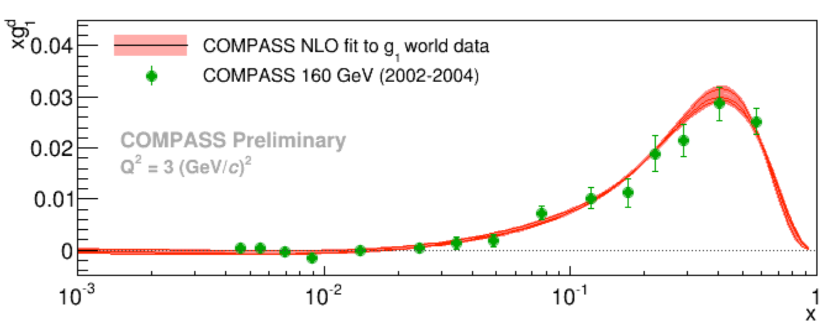




Phys.Rev. D 87 (2013) 052018

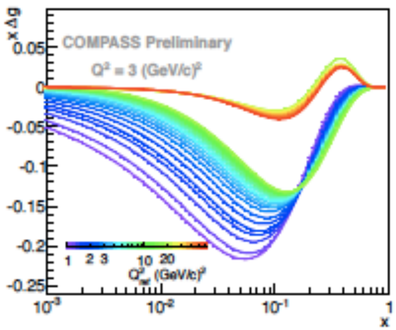
New COMPASS NLO QCD fit (inclusive, including new COMPASS proton data) M.Wilfert, DIS 2014

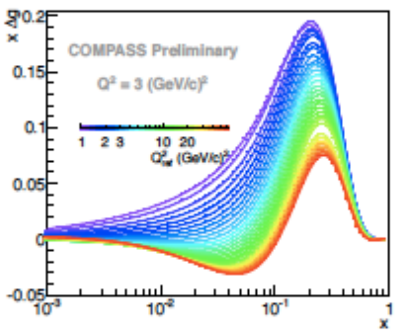


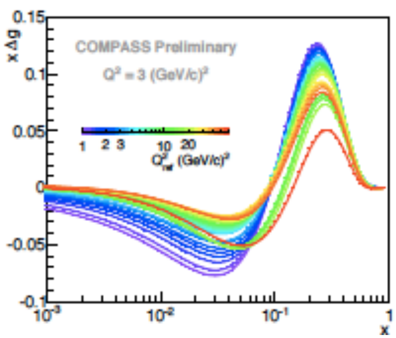


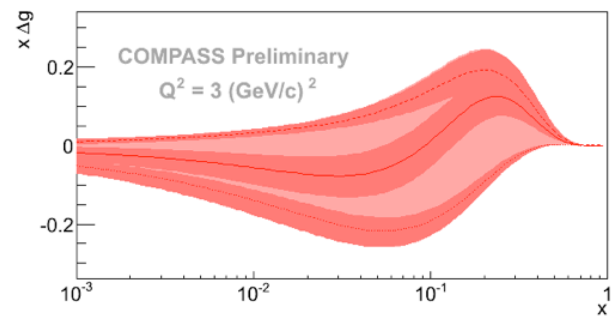
COMPASS QCD analysis

New COMPASS NLO QCD fit (inclusive, including new COMPASS proton data) M.Wilfert, DIS 2014









Large uncertainty due to different parameterization and reference scale

Gluon's contribution to nucleon spin budget not well constrained

Summary

- Gluon polarisation measurement @ COMPASS has been presented
- New results on gluon polarisation @ LO QCD approximation from high-p_T hadron pairs measurement has been shown -all-p_T method
- The determination of gluon polarisation @ LO as well as NLO QCD approximation from COMPASS open-charm data has been presented
- New results on gluon polarisation from new COMPASS QCD fits have been shown

Gluons are weakly constrained by inclusive DIS data
Direct measurements constrain gluons in limited range of x

New results from global QCD analysis prefers small positive gluon polarisation but with large uncertainties.

Thank you for your attention

PEKING UNIVERSITY

COMPASS

Constraints on ΔG from COMPASS data

Krzysztof Kurek

Spin2014

The 21st International Symposium on Spin Physics, October 20-24, 2014, Beijing, China

Backup slides

First moment of g_1 structure functions

Compass only Phys. Lett. B 647 (2007) 8

$$\Gamma_1^N(Q^2) = \frac{1}{9}\left(1 - \frac{\alpha_s(Q^2)}{\pi} + O(\alpha_s^2)\right)\left(a_0(Q^2) + \frac{1}{4}a_8\right)$$

$$a_{0|Q_0^2=3(GeV/c)^2} = 0.35 \pm 0.03(stat) \pm 0.05(syst)$$

QCD NLO

$$\Gamma_1^N(Q^2) = \frac{1}{9}C_1^S(Q^2)\hat{a}_0 + \frac{1}{36}C_1^{NS}(Q^2)a_8$$

beyond NLO

$$\hat{a}_{0|Q^2\to\infty} = 0.33 \pm 0.03(stat) \pm 0.05(syst)$$

from Y. Goto *et al.*, PRD62 (2000) 034017:
($SU(3)_f$ assumed for weak decays)
$a_8 = 0.585 \pm 0.025$

C_1 calculated behind 3 loops app.
S.A.Larin *et al.*,Phys.Lett.B404(1997)153

quark contribution to the proton spin: ~ 1/3

Triangle anomaly:

$$a_0 = \Delta\Sigma - \frac{3}{2}\frac{\alpha_S}{\pi}\Delta G$$

Master formula for determination of the gluon polarisation (large Q^2)

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

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

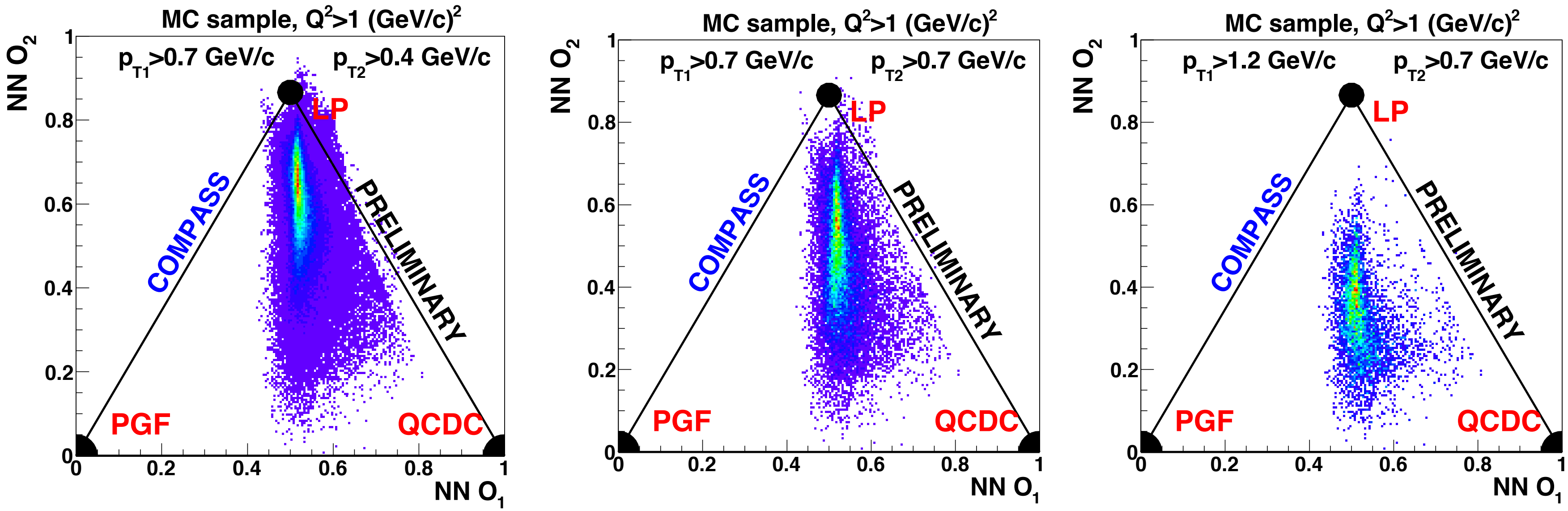
$$A^{corr} = -A_1(x_{Bj}) D \frac{R_L}{R_L^{incl}} - A_1(x_C)\beta_1 + A_1(x'_C)\beta_2$$

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

- The polarized quark contribution (LO+QCDC) are taken directly from inclusive A_1 asymmetry (pure data)
- To determine $\Delta G/G$ ($<x_G>$) from $<\Delta G/G>$, $\Delta G/G$ has been assumed to be a linear function of x_G in measured bin (very well justified assumption)

Artificial Neural Network

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

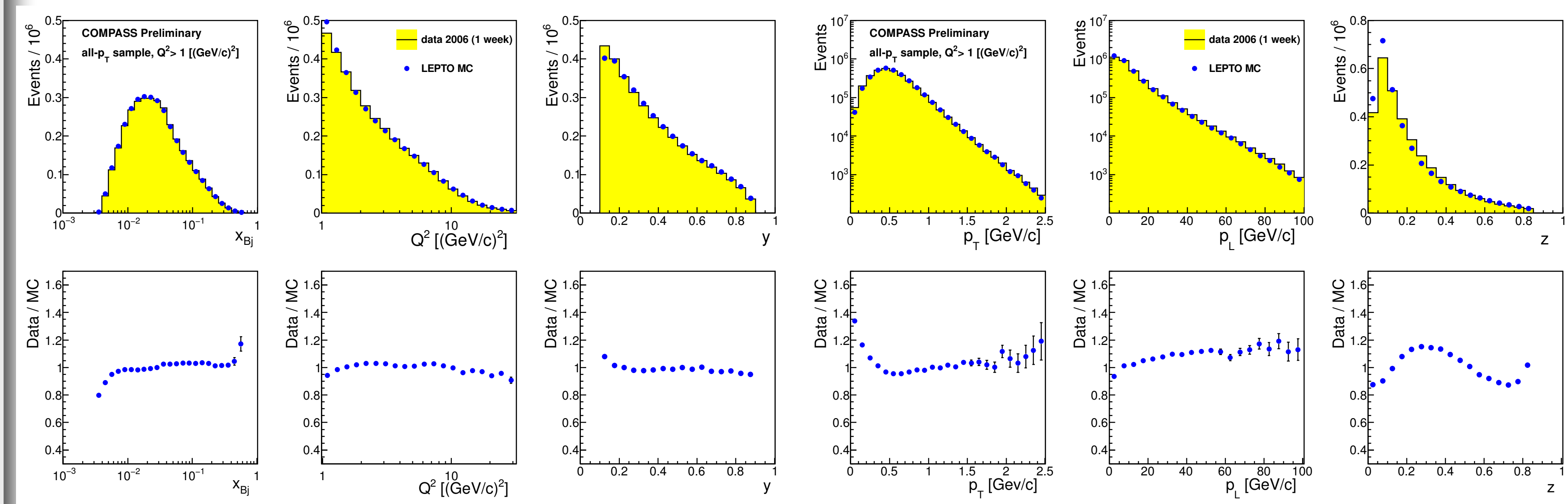


$$R_{PGF} = 1 - o_1 - \frac{1}{\sqrt{3}} o_2 \qquad R_C = o_1 - \frac{1}{\sqrt{3}} o_2 \qquad R_L = \frac{2}{\sqrt{3}} o_2$$

New analysis - all-p_T method
MC vs data

MC: same MC as in the previous analysis (high-p_T tunning) with FLUKA generator for simulating secondary interactions.

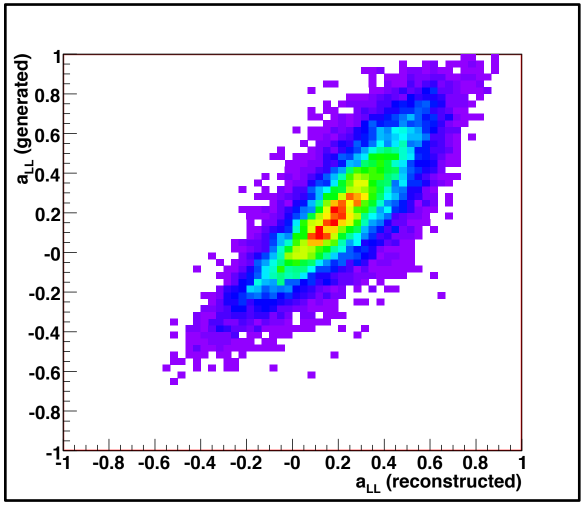
Data selection:
standard DIS cut on inclusive variables (large Q^2)
at least one charged hadron detected - no high-p_T cut !
for ANN information from one, leading hadron only is used

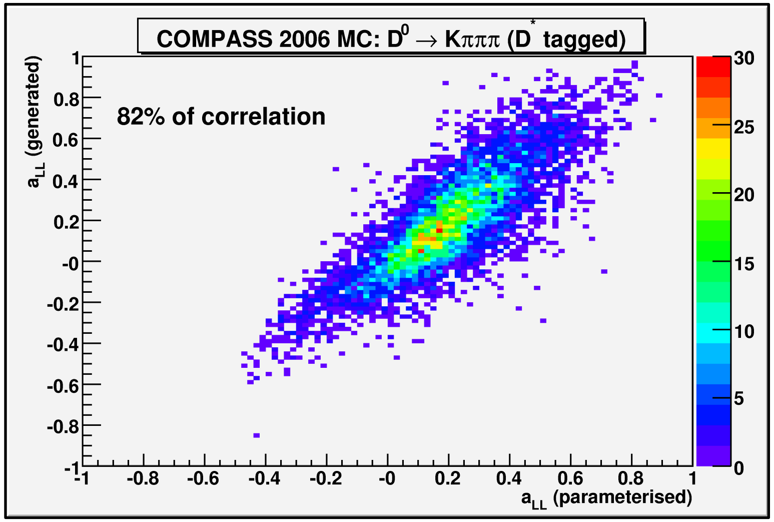


data selection and MC comparison

Partonic muon-gluon asymmetry and NN parameterization

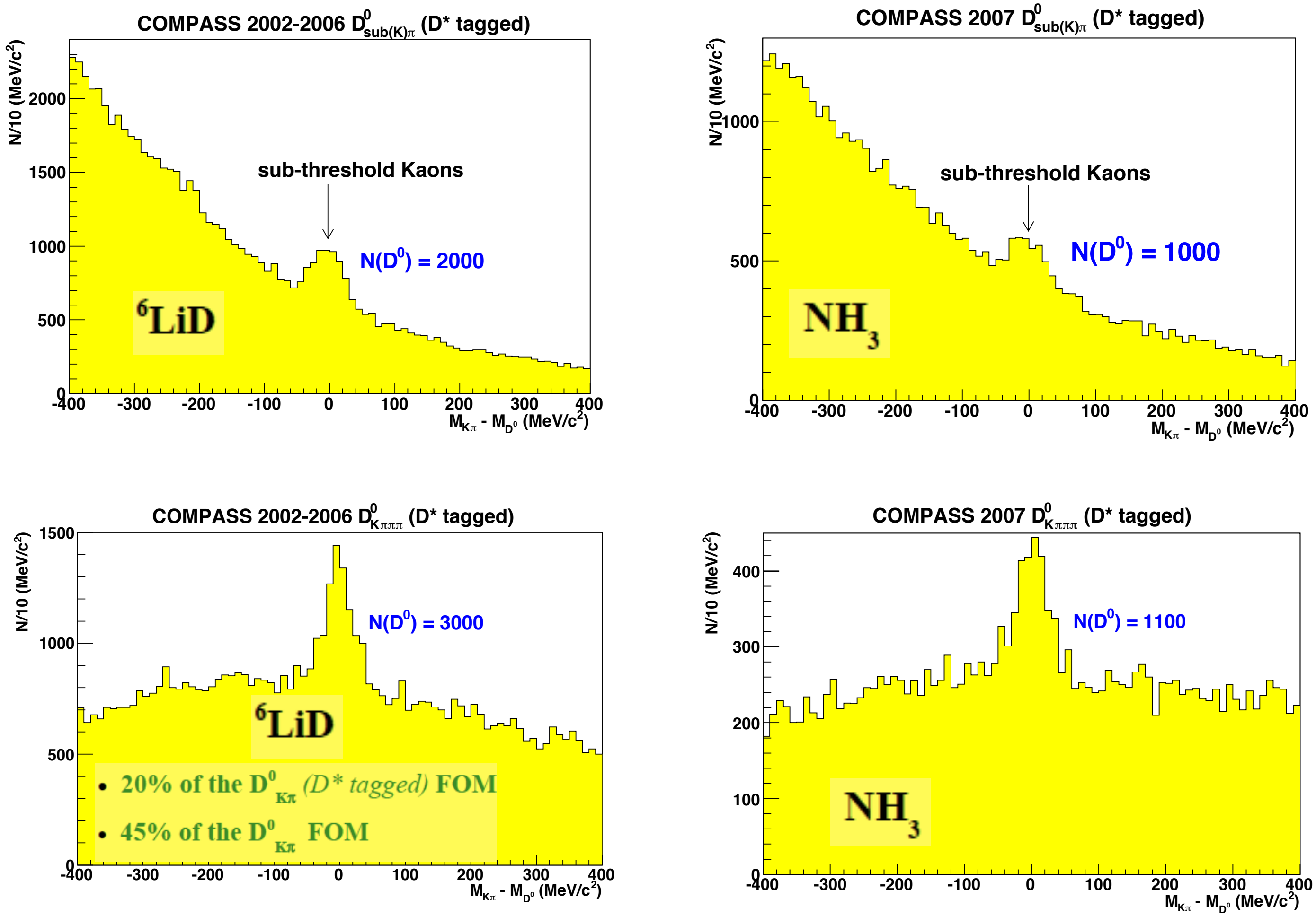
- a_{LL} depends on the knowledge of the partonic kinematics and can not be experimentally obtained - only one charmed meson is reconstructed
- a_{LL} is calculated with MC (in LO QCD) and parameterized by measured quantities using NN approach
- As a training vector kinematical variables: y, x_{Bjk}, Q^2, $z_D{}^0$, $p_{T,D}{}^0$ are used





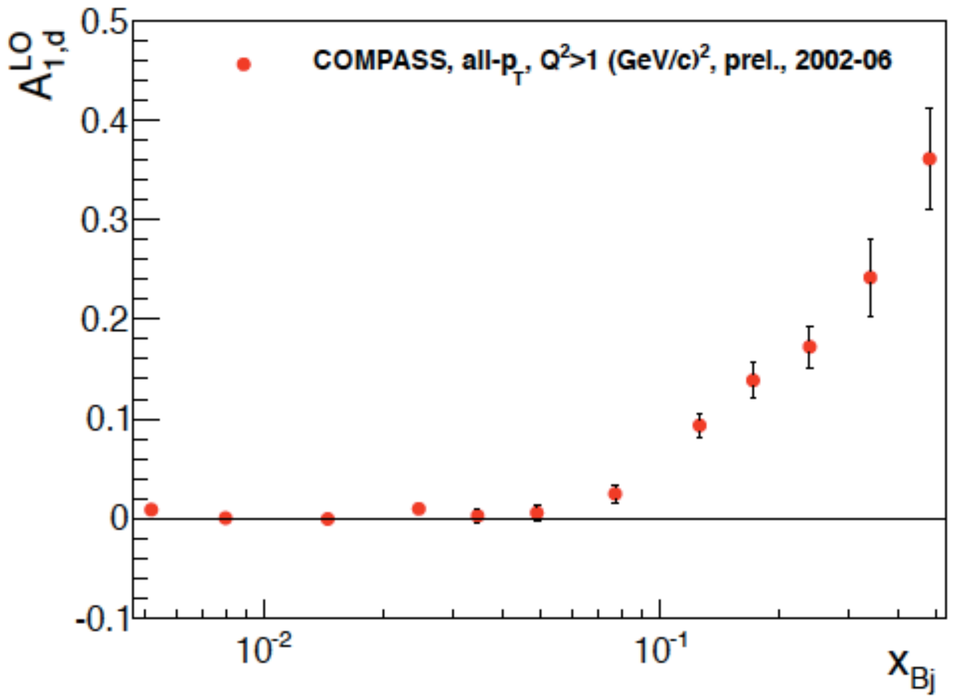
D^0 meson reconstruction

Invariant mass spectrum D^0 mesons reconstruction



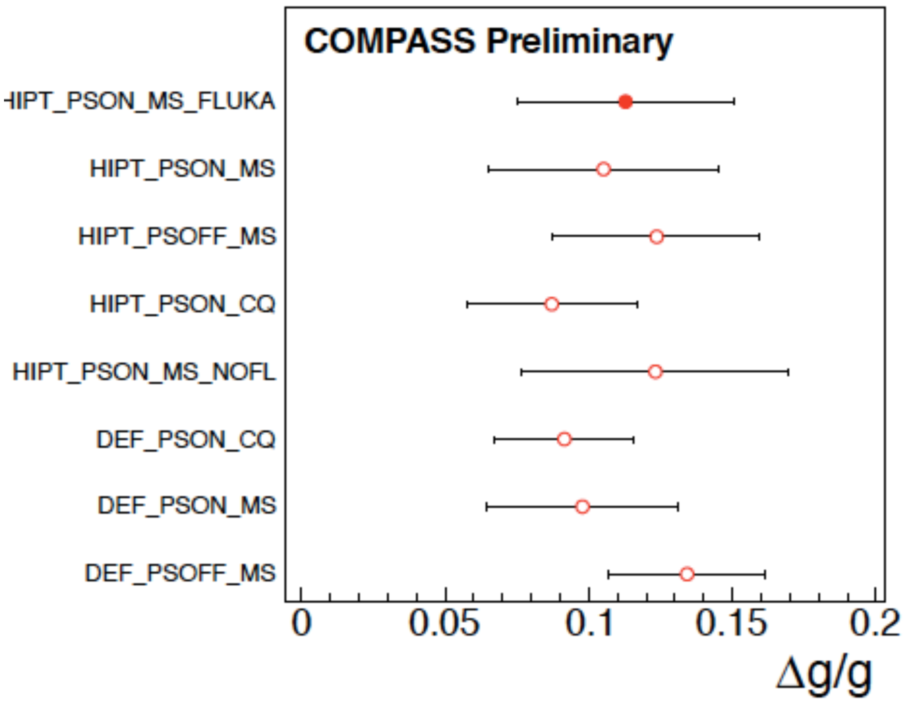
Results & systematics

- For completeness A_1^{LO} results are shown
  - extracted asymmetries are compatible with zero for low x_{Bj}
  - positive value is obtained for higher x_{Bj}, as expected



Results & systematics

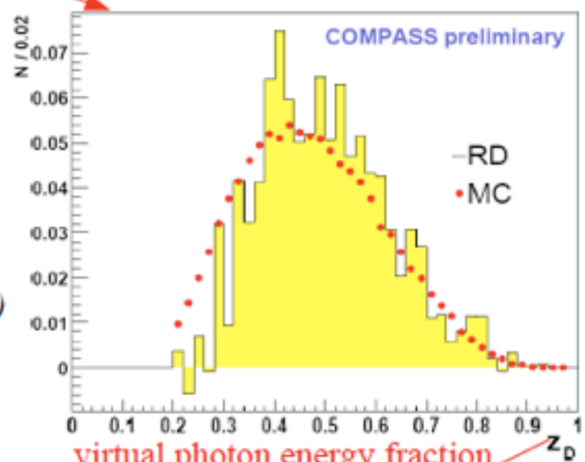
- Presented analysis is MC dependent
- 8 MC samples are used to study systematic uncertainty of $\Delta g/g$
- The extracted values of $\Delta g/g$ for each of MC are shown in figure
- The RMS of the obtained results was taken as a systematic error



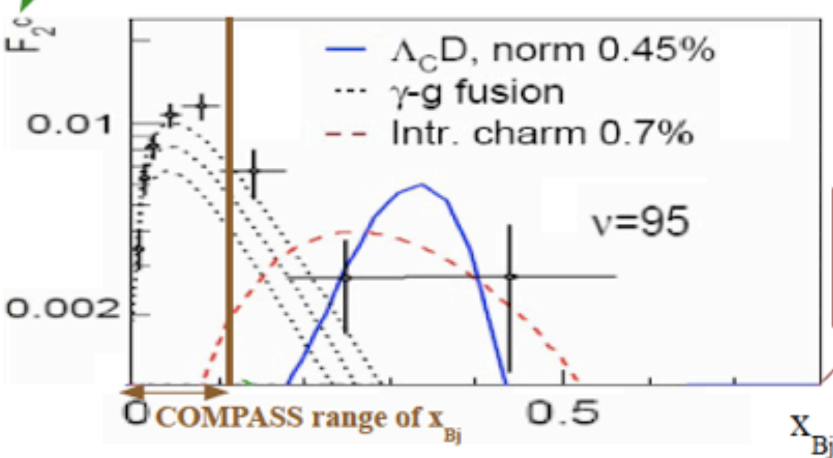
- Obtained $\Delta g/g$ results are very stable, RMS $= 0.017$
- Results are stable while the error of $\Delta g/g$ changes by up to a factor 2

Why measure gluon spin from Open-Charm?

- $c\bar{c}$ **production is dominated by the PGF process, and <u>free from physical background</u>** *(ideal for probing gluon polarisation)*
  - In our center of mass energy, the contribution from intrinsic charm *(c quarks not coming from hard gluons)* in the nucleon is negligible
  - Perturbative scale set by charm mass $4m_c^2$
  - Nonperturbative sea models predict at most <u>0.7% for intrinsic charm contribution</u>
    - Expected at high x_{Bj} *(compass $x_{Bj} < 0.1$)*
  - $c\bar{c}$ supressed during fragmentation *(at our energies)*



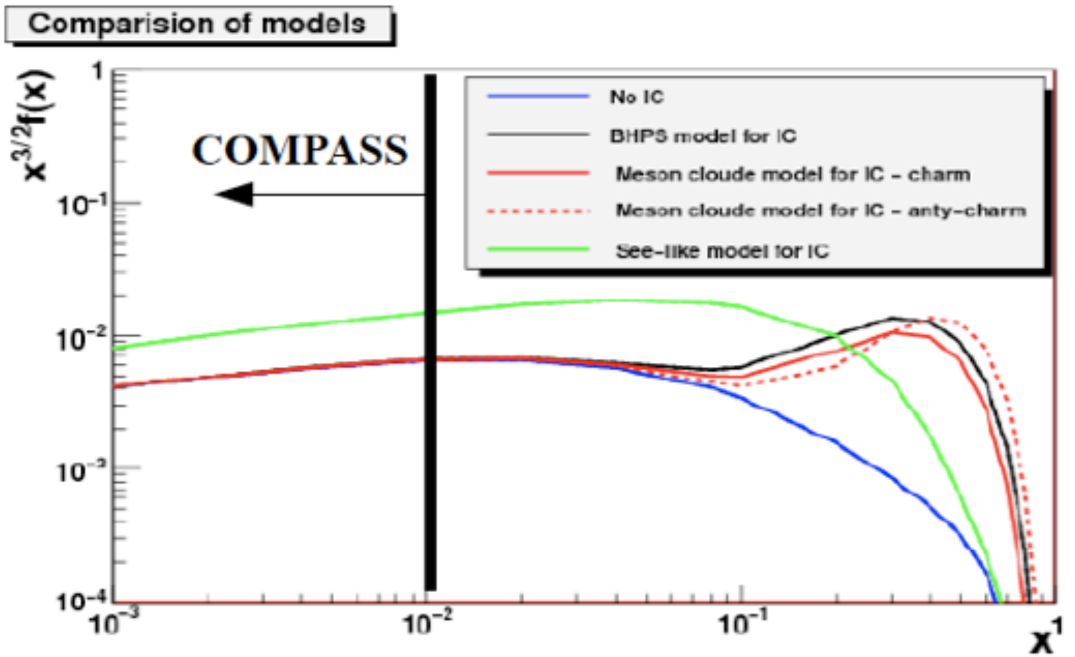
virtual photon energy fraction carried by D^0 meson



Ref. Hep-ph/0508126 and hep-ph/9508403
Phys. Lett. B93 (1980) 451
Data from EMC:Nucl.Phys.B213, 31(1983)

Intrinsic charm predictions: CTEQ6.5c

- **In the COMPASS kinematic domain:**
  - **No intrinsic charm contamination is predicted by the theory driven results**
  - **Only the more phenomenological *"See-like"* scenario should be taken into account *(under study)***



Aroma MC PS versus COMPASS data

Differential cross section for D* meson production (D* 2004 COMPASS data)