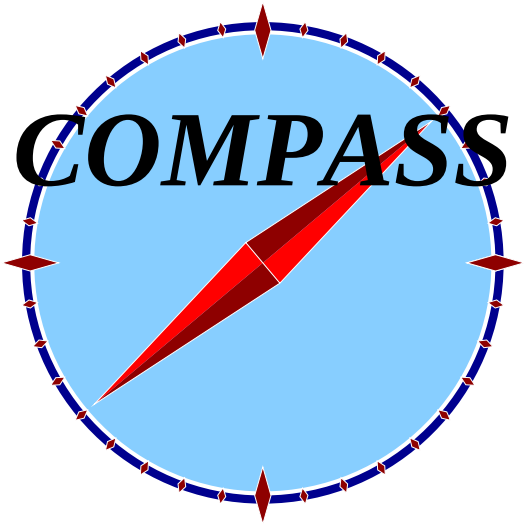
$\Delta G/G$ at COMPASS



Yann Bedfer
Saclay - DAPNIA/SPhN
On behalf of the COMPASS collaboration

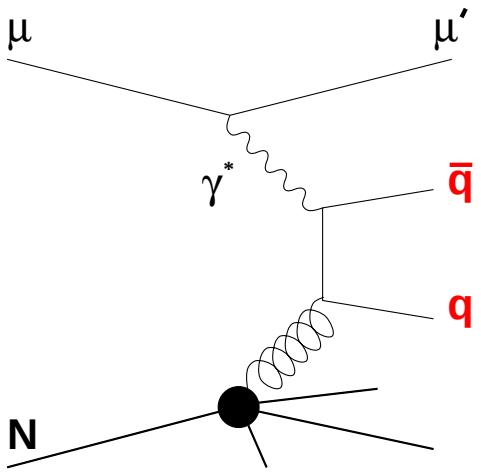
The Physics Case

- QCD fit of world Polarized DIS data (CERN, SLAC, HERMES, JLab)
  - Valence quarks polarized distributions well fixed.
  - Gluon polarization largely undetermined
    (for lack of Q^2 lever-arm in the g_1 data)
  - Shapes of sea-quark and gluon distributions cannot be separately determined.

$\Rightarrow$ Need for a direct measurement of $\Delta G/G$

- Probe the role of the axial anomaly in the suppression of $\int g_1 dx$

$\Delta G/G$: Photon Gluon Fusion



q = c : Open Charm production
- Triggered by PGF at LO (neglecting Intrinsic Charm)

⇒ Theory Golden Channel
- Experimentally difficult
- pQCD scale set by $\hat{s} > 4m_c^2$

q = u,d,s,c : High p_T Hadrons
- Competing LO-DIS, QCD-Compton and resolved photon processes.

⇒ Theoretical uncertainties.
- Higher statistics
- pQCD scale set by p_T

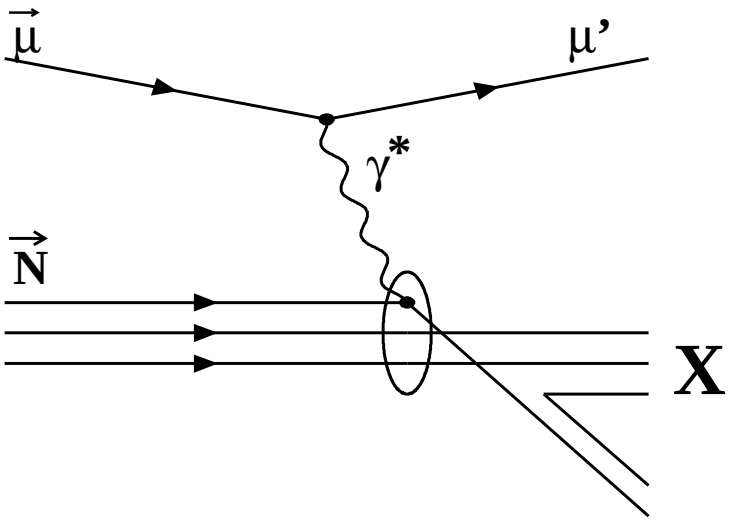
⇒ Explore all Q^2

Asymmetry Measurement

- Two oppositely polarized target cells : $upstream$, $downstream$
- Polarization reversal by field rotation every 8 hours

$$\frac{A_{\parallel}}{D} = \frac{1}{P_T P_B f D} \; \frac{1}{2}\left(\frac{N_u^{\uparrow\downarrow} - N_d^{\uparrow\uparrow}}{N_u^{\uparrow\downarrow} + N_d^{\uparrow\uparrow}} + \frac{N_d^{\uparrow\downarrow} - N_u^{\uparrow\uparrow}}{N_d^{\uparrow\downarrow} + N_u^{\uparrow\uparrow}} \right)$$

- Polarization reversal by microwave reversal : $u \leftrightarrow d$



- Target polarization $P_T \simeq 50$ %
- Beam polarization $P_B \simeq 76$ %

- Dilution factor $\langle f \rangle \simeq 40$ %
- Depolarization factor $\langle D \rangle \simeq 60$ %

Data Taking

- Data taking

	2002	2003	2004
Days (*effective, longitudinal*)	43	36	54
Integrated Luminosity (fb^{-1})	0.45	0.80	1.12

- Analyzed (preliminarily) : 2002 and 2003 $\Rightarrow \sim 1/2$ of collected data

- COMPASS resumes data taking in 2006,
  w/ an improved experimental apparatus.

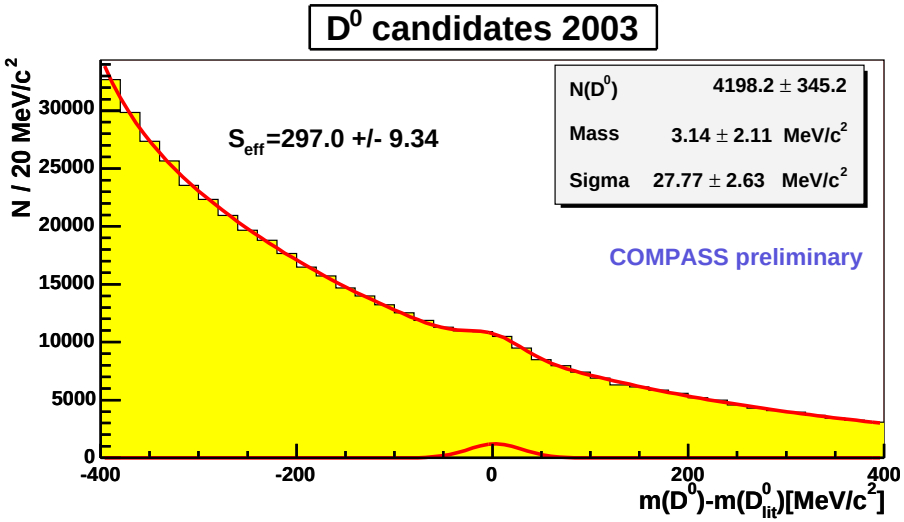
Open Charm : D^o Reconstruction

- $D^o \to K\pi$
  - Thick target
  - $\Rightarrow$ No Charm decay vertex reconstruction

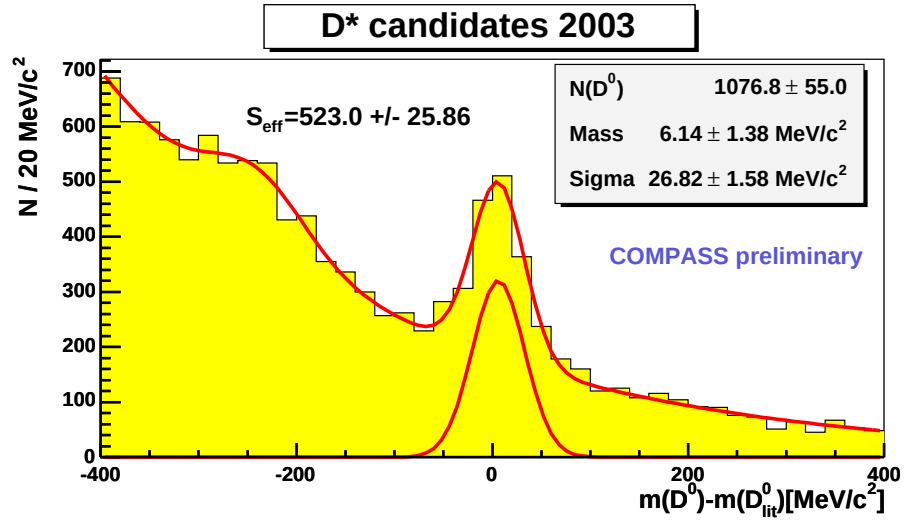
($N.B.$: $\mathrm{S_{eff}}$ *is the effective number of events*

$$\mathrm{S_{eff}} = \mathrm{S}^2/(\mathrm{S}+\mathrm{B})$$

where S *and* B *are signal and background counts.*)



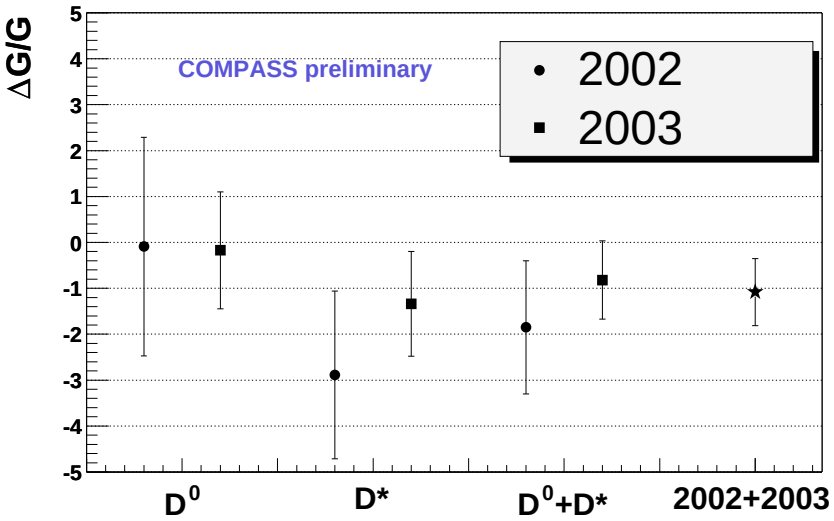
- Favorable case : D^o from D^*
  - $1/3$ of D^o's
  - $D^* \to D^o\pi \to K\pi\pi$
  - D^* tagging by cut on 3-body invariant mass



Open Charm : $\Delta G/G$

- Special care is taken to optimize the use of data :
  Event by event weighting

$$\Delta G/G = \frac{1}{P_T} \frac{\sum_i^{\uparrow\downarrow} w_i - \sum_i^{\uparrow\uparrow} w_i}{\sum_i^{\uparrow\downarrow} w_i^2 + \sum_i^{\uparrow\uparrow} w_i^2} \qquad w_i = \frac{(f\, P_B \langle a_{LL} \rangle)_i}{(1 + B/S)_i}$$



- $\langle a_{LL} \rangle (y, p_T, z_D)$ derived from MC
  - AROMA generator, [Ref. : *Ingelman*]
  + POLDIS [Ref. : *Bravar*]

$$\Delta G/G = -1.08 \pm 0.73(stat.)$$
$$x_g = 0.15 \pm 0.08\, RMS$$

(*N.B. : Preliminary result.*)

Open Charm : Outlook

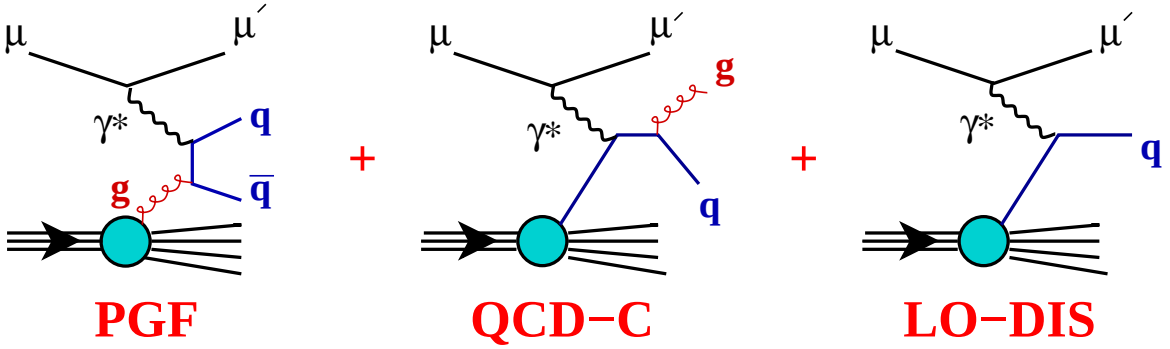
- Clear lack of statistics,
  even if one takes into account 2004 data (factor $\times 2$)

- Resuming data taking in 2006
  w/ improved experimental apparatus :

  - New target solenoid, w/ aperture $\times 2$
  - RICH upgrade
    $\Rightarrow$ Suppression of background under the D^o peak.
  - Electromagnetic calorimeters
    $\Rightarrow$ Explore D^o decay channels w/ a π^o in the final state, mainly :
    $D^o \to K\pi\pi^o \qquad BR = 13\% \qquad (BR(D^o \to K\pi) = 3.8\%)$

High p_T Hadrons

- Competing processes to PGF
  - $Q^2 > 1$



  - All Q^2 + Resolved photon processes

    $\Rightarrow$ Dependence upon, poorly known, polarized structure of the photon

$\Rightarrow$

$$A_{\parallel} = R_{PGF}\, a_{LL}^{PGF}\, \Delta G/G \;+\; A_{background}$$

where R_{PGF} fraction of PGF events
and $a_{LL}^{PGF} = d\Delta\sigma_{PGF}^{\mu g}/d\sigma_{PGF}^{\mu g}$
and $A_{background}$
need be determined by a simulation of the experiment.
$\Rightarrow$ Model dependent in the evaluation of $\Delta G/G$

High p_T Hadrons : $Q^2 > 1$ *vs.* $Q^2 < 1$

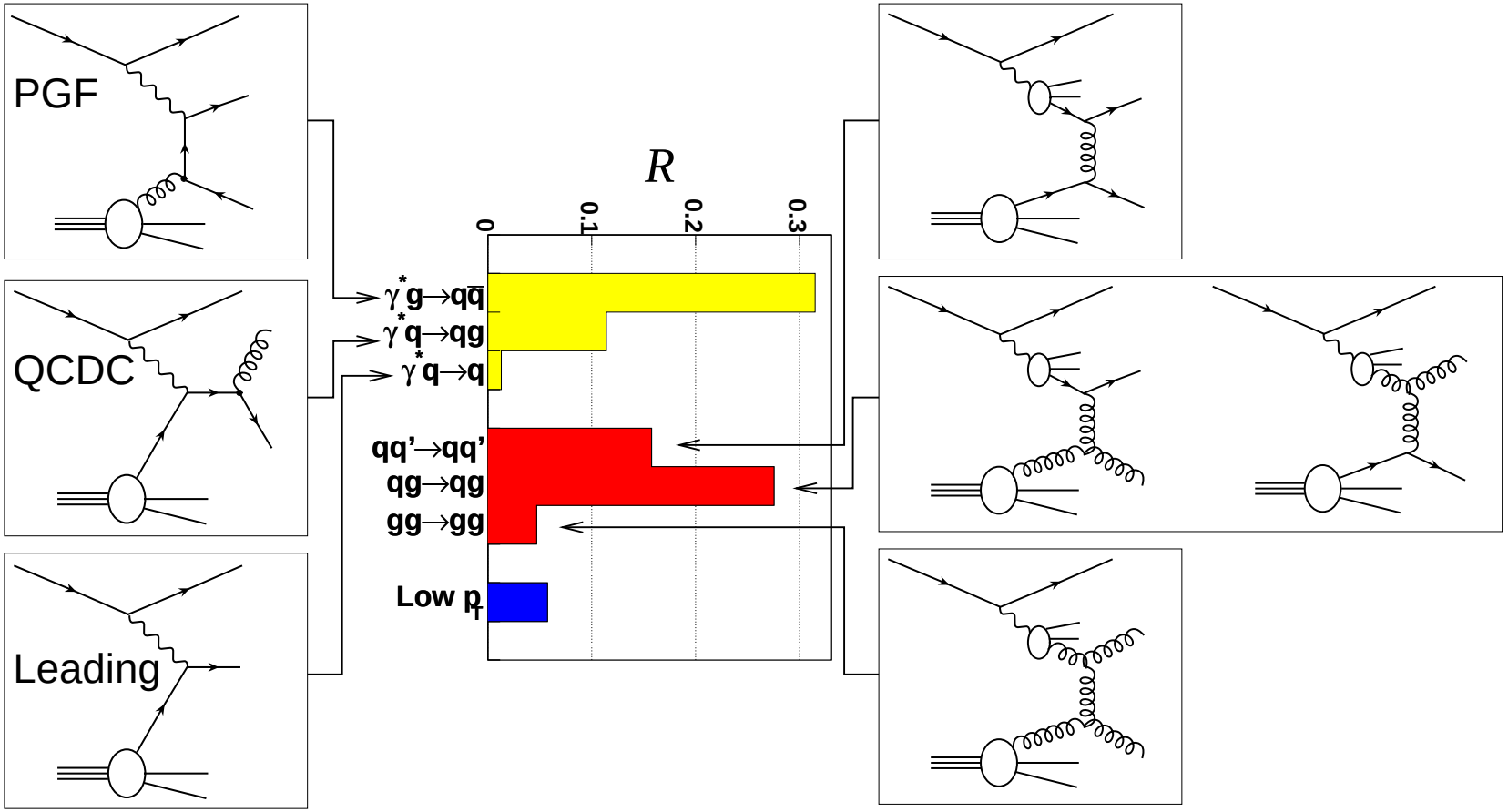
- 2 different analyzes :
  - $Q^2 > 1$ 10% of data LEPTO
  - $Q^2 < 1$ 90% of data PYTHIA

- For both, consistent LO analysis :
  - LO PDFs,
  - LO expressions for analyzing powers,
  - Parton showers turned off in JETSET.

- For both, 2 high p_T hadrons required :
  (*N.B. : No jets at fixed target energies but leading hadrons reflect original partons distribution.*)
  - High p_T cut : $p_T^1, p_T^2 > 0.7\,GeV$, $(p_T^1)^2 + (p_T^2)^2 > 2.5\,GeV^2$
  - Exclude target fragmentation : $x_F > 0.1$
  - Exclude hadron systems w/ invariant mass $< 1.5\,GeV$

High p_T at $Q^2 < 1$: PYTHIA processes

- R = fraction of total cross-section for given process.



N.B. : $qg \to qg$ and $gg \to gg$ sensitive to G in the nucleon.
Contributions of longitudinal photons not shown.

High p_T at $Q^2 < 1$: Contributions to the asymmetry

$$\langle \frac{A_\parallel}{D} \rangle = R_{PGF} \langle \frac{a_{LL}^{PGF}}{D} \rangle \frac{\Delta G}{G} + R_{QCDC} \langle \frac{a_{LL}^{QCDC}}{D} A_1 \rangle$$

$$+ \sum_{f,f'=u,d,s,\bar{u},\bar{d},\bar{s},G} R_{ff'} \langle a_{LL}^{ff'} \frac{\Delta f^\gamma}{f} \frac{\Delta f'^N}{f'} \rangle$$

$$+ R_{Leading} A_{Leading} + R_{Low-p_T} A_{Low-p_T}$$

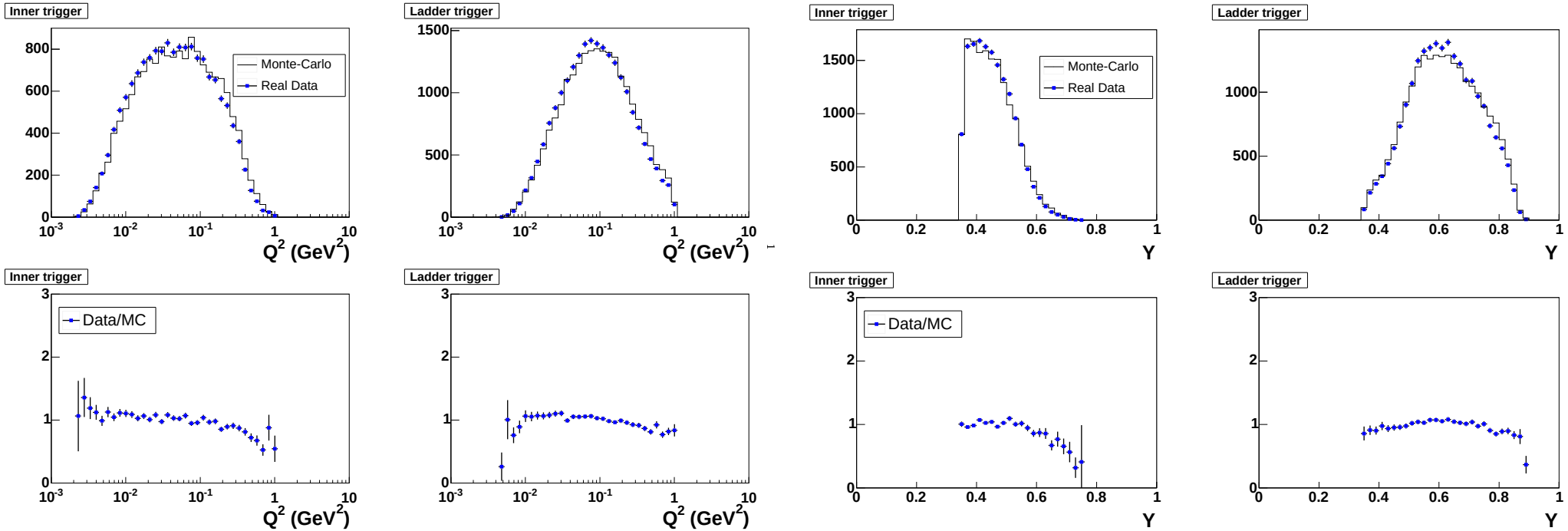
- Resolved photon terms :
  - $\Delta f^\gamma = \Delta f^\gamma_{q\bar{q}} + \Delta f^\gamma_{VMD}$; $\Delta f^\gamma_{q\bar{q}} \leftarrow QED + QCD$, Δf^γ_{VMD} unknown.

  $\Rightarrow$ Min. and max. scenarios : $-f^\gamma_{VMD} < \Delta f^\gamma_{VMD} < f^\gamma_{VMD}$

  [Ref. : *Glück, Reya, Sieg*]

- $Leading$ and $Low - p_T$ terms neglected.

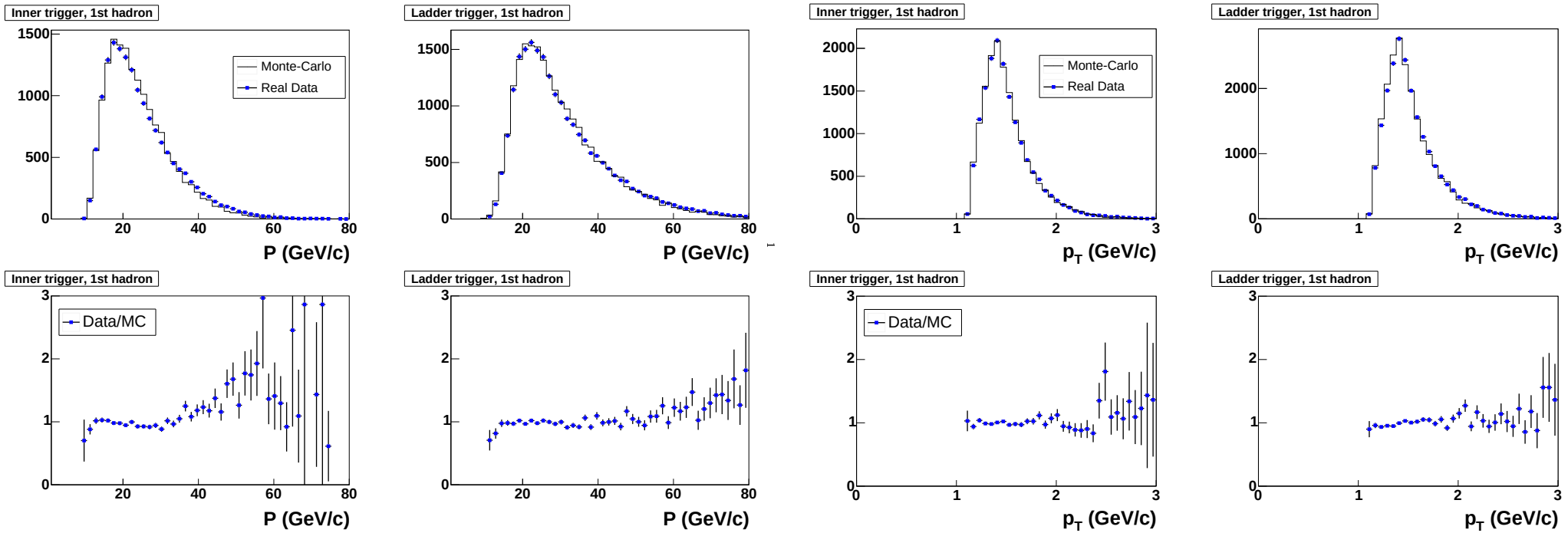
High p_T at $Q^2 < 1$: Data *vs.* MC, Inclusive variables



- Good agreement reached using GRV98 PDFs.
- $0.35 < y < 0.9$
  - Low cut removes events w/ low sensitivity to G.
  - Hight cut removes radiative events.

High p_T at $Q^2 < 1$: Data *vs.* MC, Hadron variables

- Tuning of the intinsic k_T^γ in the resolved photon for simultaneous agreement on p and p_T.



- Agreement for the 2nd, sub-leading, hadron is equally good.

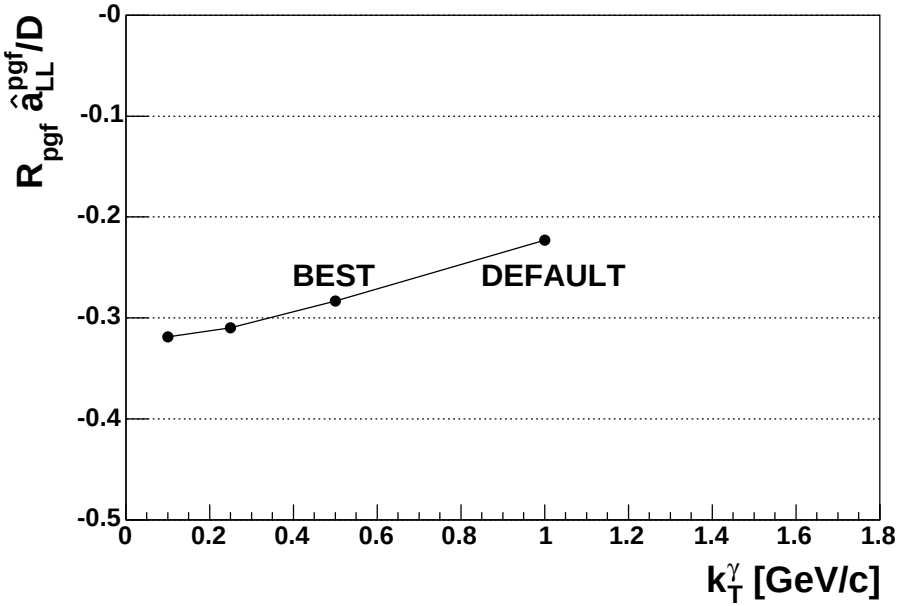
High p_T at $Q^2 < 1$: Systematics

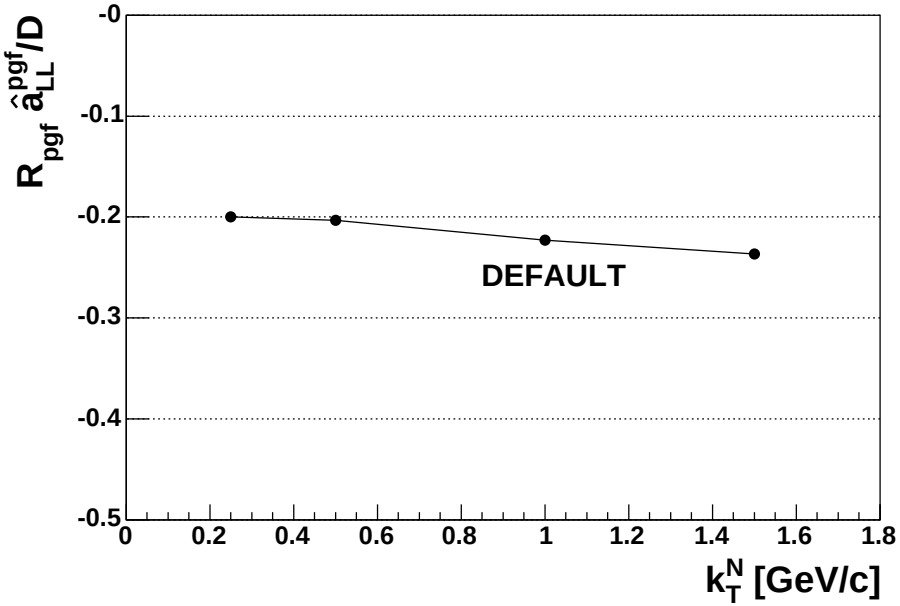
- Experimental
  Evaluated on large statistics sample w/o p_T cut
  for which physical asymmetry is expected to be zero.

- MC :
  Explore PYTHIA parameter space :
  - Parameters generating p_T :
    Parton fragmentation,
    Primordial k_T in the nucleon and in the photon.
    varied in the range where fair agreement w/ experimental data.
  - Parameters related to NLO :
    Renormalization/factorization scale,
    Parton showers (ON/OFF).

High p_T at $Q^2 < 1$: Systematics ($cont'd$)

- Example : Impact of k_T on $R_{PGF} \times a_{LL}^{PGF}/D$





High p_T at $Q^2 < 1$: Results

$$A_{\parallel}/D = 0.002 \pm 0.019(stat.) \pm 0.003(syst.)$$

I) Considering separately the min. and max. scenarios for the polarized photon :

$$\left(\frac{\Delta G}{G}\right)_{min.} = 0.016 \pm 0.068(stat.) \pm 0.011(exp.syst.) \pm 0.018(MC syst.)$$

$$\left(\frac{\Delta G}{G}\right)_{max.} = 0.031 \pm 0.089(stat.) \pm 0.014(exp.syst.) \pm 0.052(MC syst.)$$

II) Lumping together all systematics, including MC and diff. between scenarios :

$$\Delta G/G = 0.024 \pm 0.089(stat.) \pm 0.057(syst.)$$
$$x_g = 0.095^{+0.08}_{-.04}$$
$$\mu^2 \simeq 3\, GeV^2$$

High p_T at $Q^2 > 1$: Preliminary Results

- Kinematical cuts :
  - $0.1 < y < 0.9$
  - $x < .05 \quad \Rightarrow \quad A_1^d \simeq 0$
    $\Rightarrow$ $QCDC$ and $LO - DIS$ can be neglected.

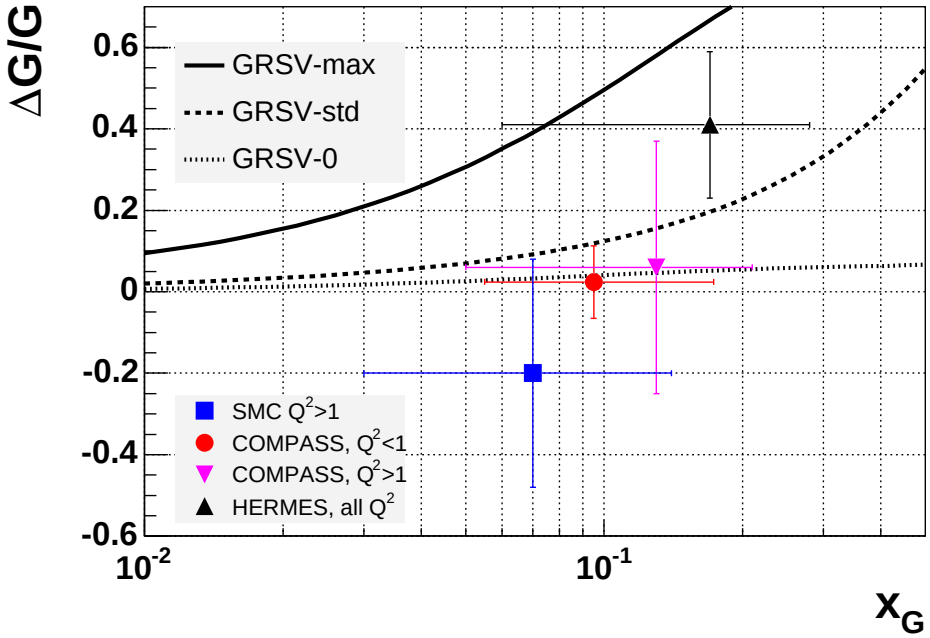
$$A_{\parallel}/D = -0.015 \pm 0.080(stat.) \pm 0.013(syst.)$$

- LEPTO generator tuned to reproduce experimental data
  (parameters of the fragmentation)
  $\Rightarrow \langle a_{LL}/D \rangle = -0.75 \pm 0.05$
  $\Rightarrow R_{PGF} = 0.33 \pm 0.007$

$$\Delta G/G = 0.06 \pm 0.31(stat.) \pm 0.06(syst.)$$
$$\langle x_g \rangle = 0.15 \pm 0.08\, RMS$$

(*N.B. : Quoted syst. does not include any MC contributions.*)

High p_T : Comparison w/ QCD fits



- Parameterizations from NLO fits [Ref. : *Glück, Reya, Stratmann, Vogelsang*]
  - w/ various assumptions on ΔG at input scale,
  - evolved to $\mu^2 = 3\,GeV^2$.

$\Rightarrow$ COMPASS favors fits w/ lower gluon polarisation.

High p_T : Summary and Outlook

- Open charm : Model independent, need more data.

- High p_T : Model dependent
  - $Q^2 < 1\,GeV^2$: limited impact of uncertainty on polarized photon structure
    $\Rightarrow$ $\Delta G/G_{(x_g=.095)} = 0.024 \pm 0.089(stat.) \pm 0.057(syst.)$ assuming PYTHIA.
  - Including 2004 data :
    $Q^2 > 1\,GeV^2$: $\delta\Delta G/G(stat.) = 0.22$
    $Q^2 < 1\,GeV^2$: $\delta\Delta G/G(stat.) = 0.065$
  - Further improvements :
    $Q^2 > 1\,GeV^2$: Use Neural Network to improve over R_{PGF} from p_T cut.
    $Q^2 < 1\,GeV^2$: 2 bins in x_g
    NLO using calculations $\grave{a}\ la$ Regensburg [Ref. : $J\ddot{a}ger,\ Stratmann,\ Vogelsang$]

- Resuming data taking in 2006, w/ improved experimental apparatus.