Measurements of the Gluon Polarization in the Nucleon at COMPASS

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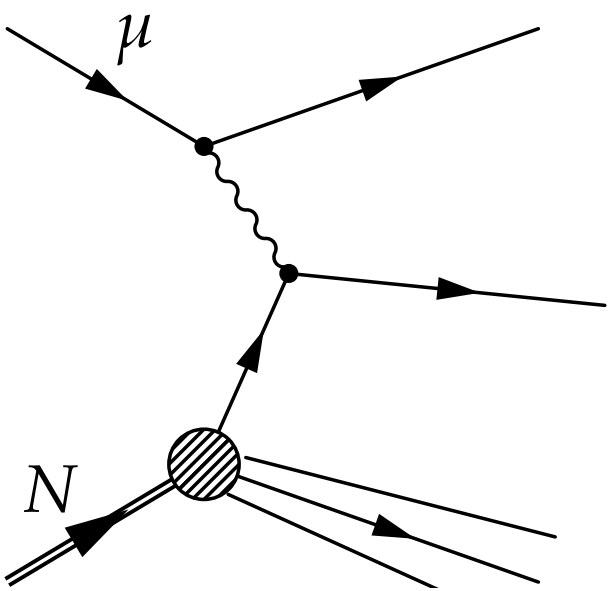
The Spin of the Nucleon

Decomposition of the Nucleon Spin

$$J_N = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_{q+g}$$

- only quark polarization well known,
  $\Delta\Sigma = 0.30 \pm 0.01 \pm 0.02$ [PLB 647 (2007) 8-17]
- gluon polarization extracted indirectly from QCD fits
- direct measurements of ΔG desirable

Deep Inelastic Lepton Scattering



DIS Variables

$$q = p_\mu - p'_\mu = (\nu, \vec{q})$$

$$Q^2 = -q^2 = \vec{q}^2 - \nu^2$$

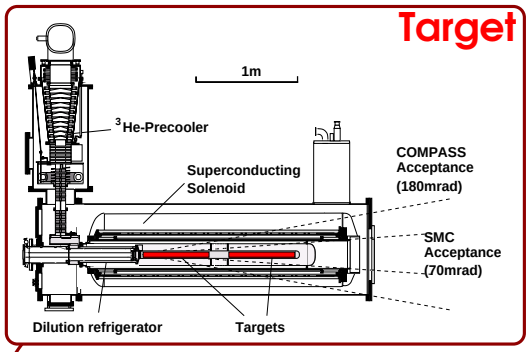
$$x_B = \frac{Q^2}{2M\nu} \qquad \in [0,1]$$

$$y = \frac{\nu}{E_\mu} \qquad \in [0,1]$$

Attention

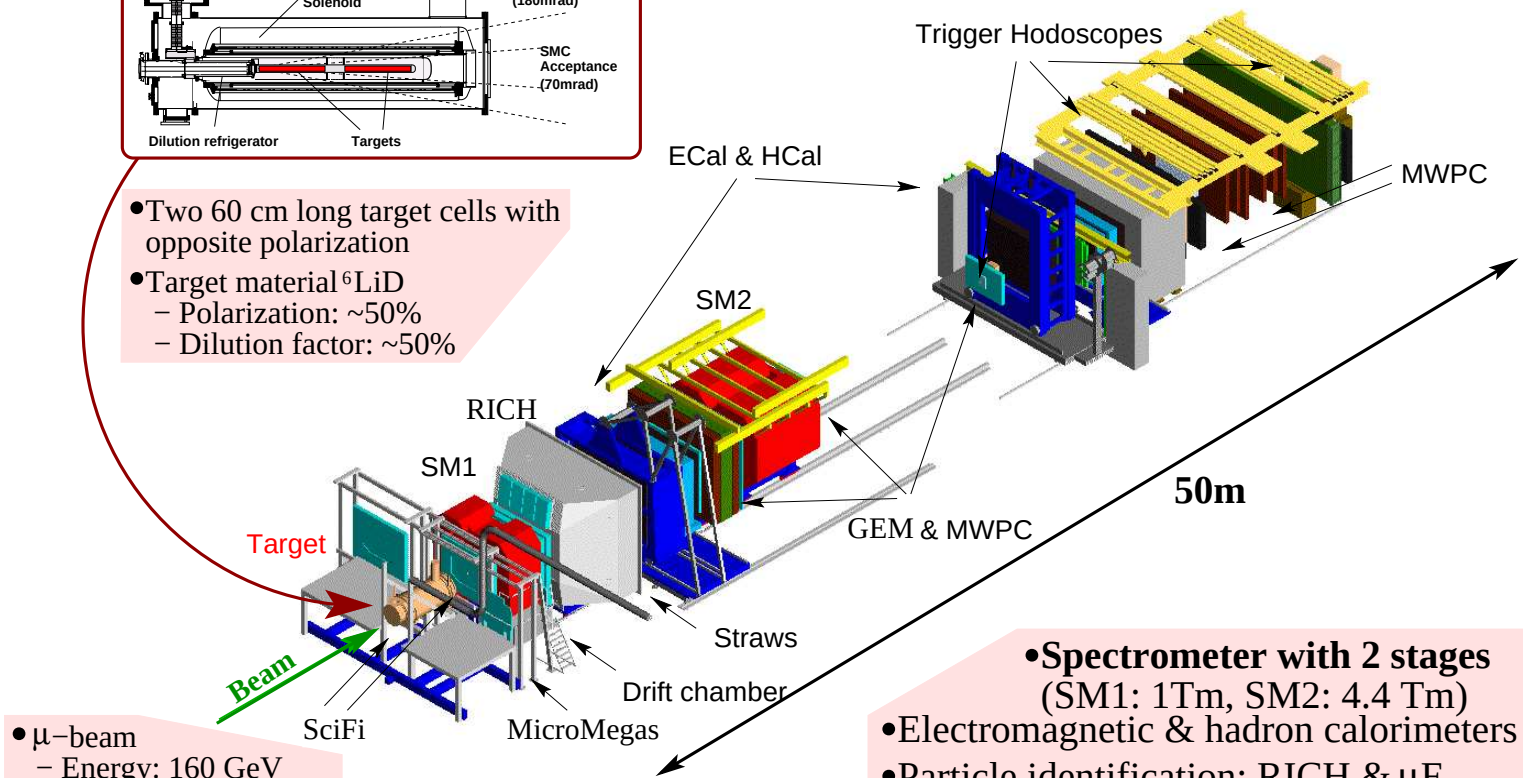
p_T is the transverse momentum of the produced hadron with respect to the virtual photon direction

The COMPASS experiment at CERN



- Two 60 cm long target cells with opposite polarization
- Target material ^{6}LiD
  - Polarization: ~50%
  - Dilution factor: ~50%

Spectrometer

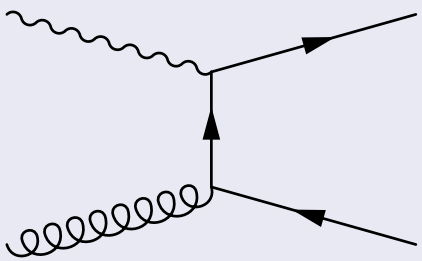


- μ−beam
  - Energy: 160 GeV
  - Intensity: $2 \cdot 10^8$ μ/spill
  - Polarization: −76%

- **Spectrometer with 2 stages** (SM1: 1Tm, SM2: 4.4 Tm)
- Electromagnetic & hadron calorimeters
- Particle identification: RICH & μF

Accessing the Gluon Polarization

photon–gluon fusion (PGF)



luminosity

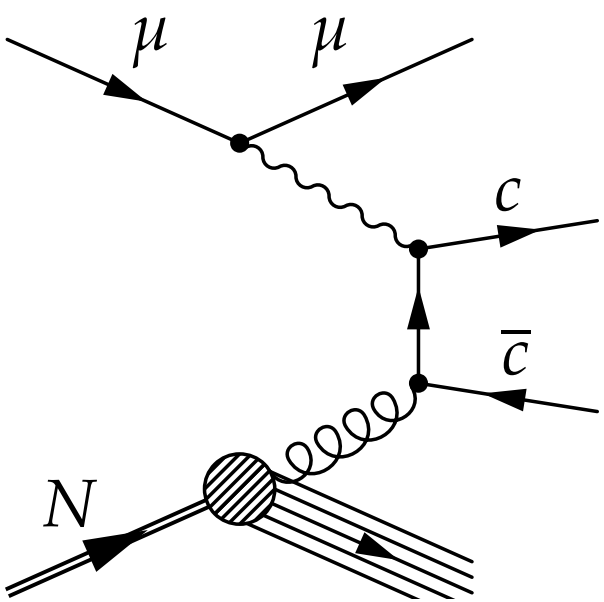
$$\mathcal{L} \approx 1.5\,\mathrm{fb}^{-1}$$

from the three years 2002–2004

four pursued methods

	process	scale	statistics	systematics	status
open charm	$g\gamma \to c\bar{c}$	m_c	low	excellent	released
high p_T pairs $Q^2 > 1$	$g\gamma \to q\bar{q}$	Q^2	medium	very good	released (2002–2003)
high p_T pairs $Q^2 < 1$	$g\gamma \to q\bar{q}$	p_T	high	good	published (2002–2003)
high p_T singles $Q^2 < 0.5$	$g\gamma \to hX$	p_T	very high	good	in preparation

Accessing the Gluon Polarization: Open Charm

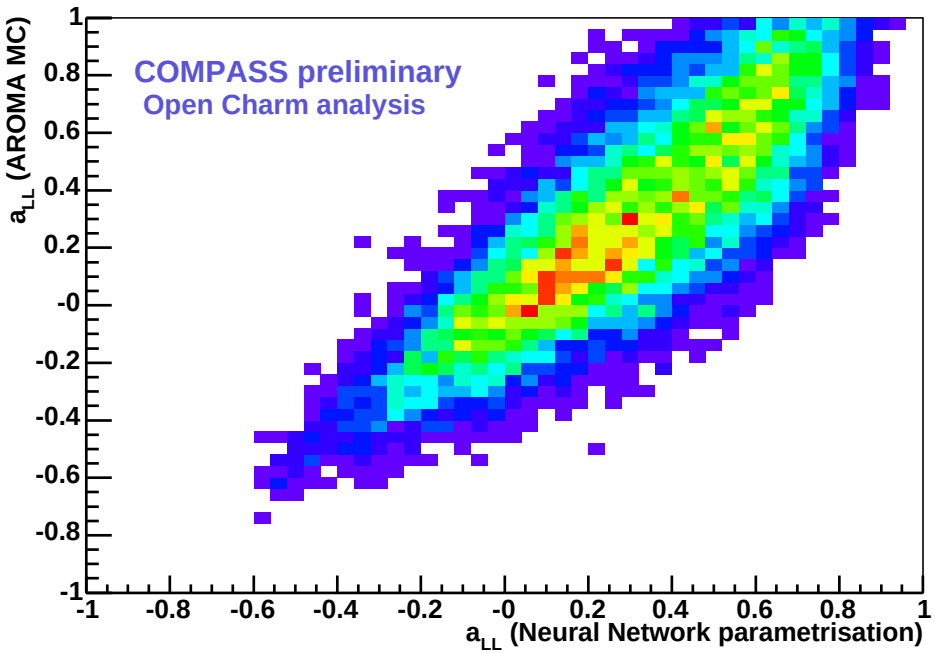


- negligible background from LO process
- reconstruct D mesons in the final state
  - requires PID
  - challenging with polarized solid state target
  - D^* tagging
- analyzing power a_{LL} calculable, MC needed for gluon kinematics

Extraction Formula (simplified wrt. event weighting)

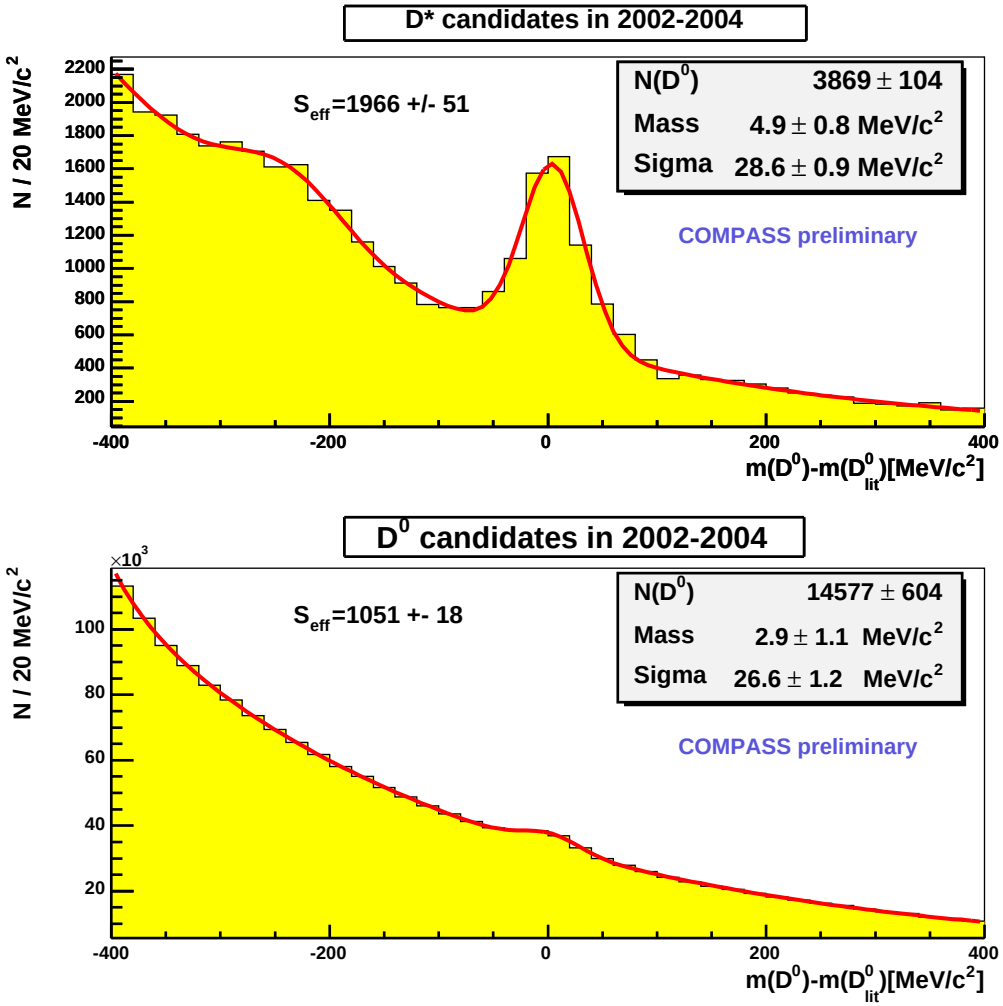
$$A_{\text{exp}} = \frac{N^{\Rightarrow} - N^{\Leftarrow}}{N^{\Rightarrow} + N^{\Leftarrow}} = f P_{\text{beam}} P_{\text{target}} \langle a_{LL} \rangle \frac{S}{S+B} \frac{\Delta G}{G} + A_{\text{bk}}$$

Open Charm: Analyzing Power



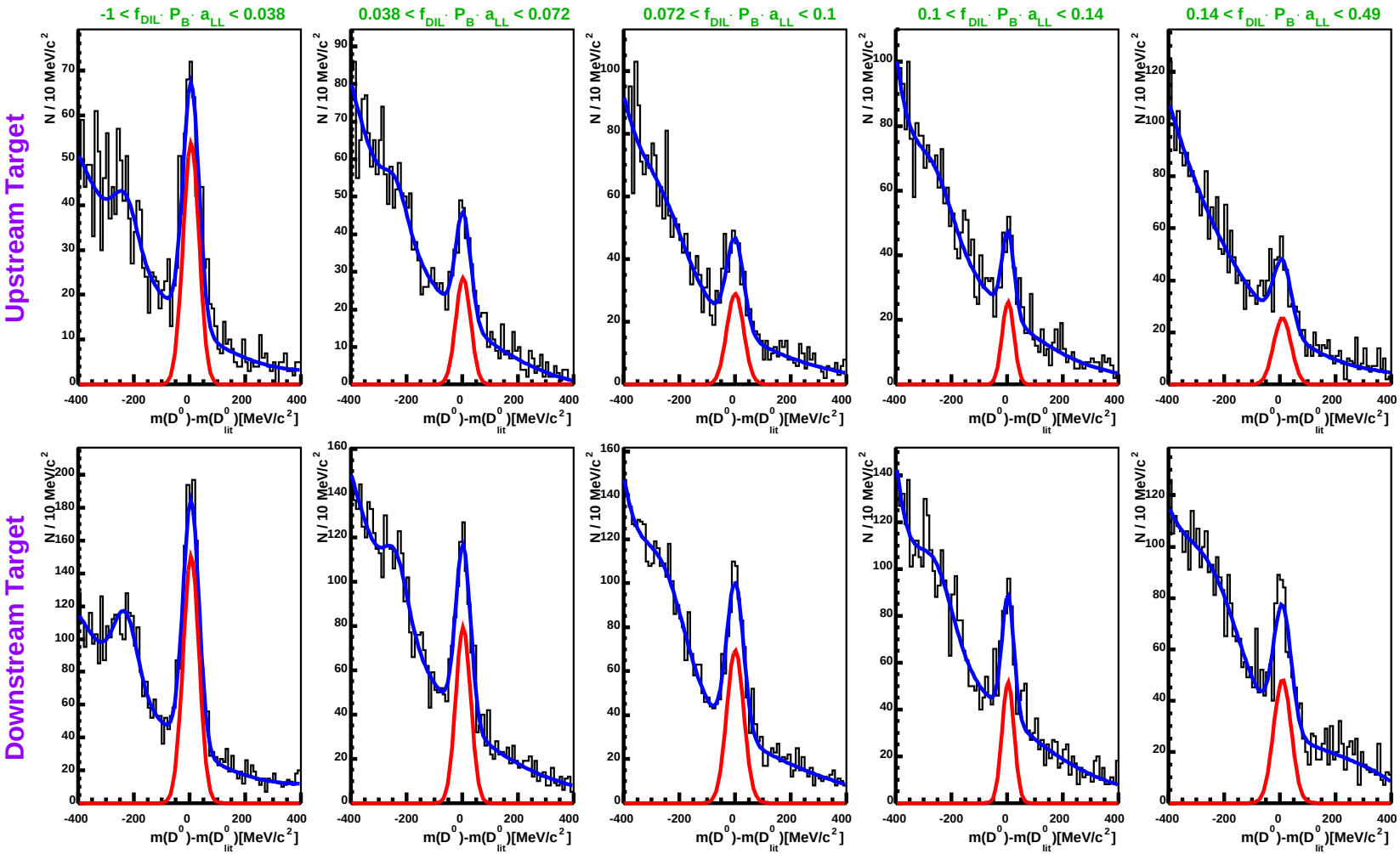
- hard scattering matrix element calculated in LO needs gluon kinematics
- AROMA Monte Carlo used for simulation
- a_{LL} estimated event-by-event from neural network parameterization and used in weighting

Open Charm: Signal/Background

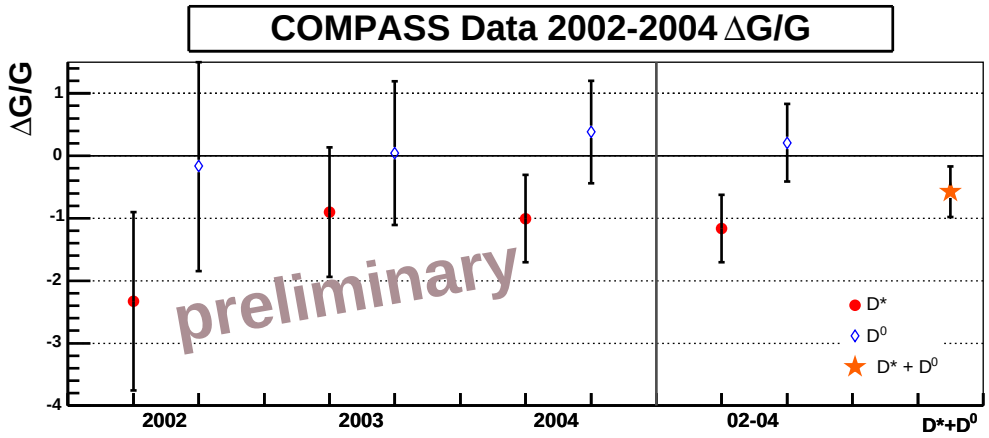


- two channels:
  - $D^0 \to \pi K$: identified πK pair (RICH)
  - $D^* \to D^0 \pi$: tagged by additional π
- $S/(S+B)$ parameterized by fitting spectra in bins of a_{LL}, then also used in event weighting (two-pass analysis)

Open Charm: Signal/Background



Open Charm: Result



Systematic Error

background asymmetry	0.07
binning procedure	0.04
false asymmetries	0.10
fitting procedure	0.09
AROMA parameters	0.05
target polarization	0.03
beam polarization	0.03
dilution factor	0.03

Result (preliminary)

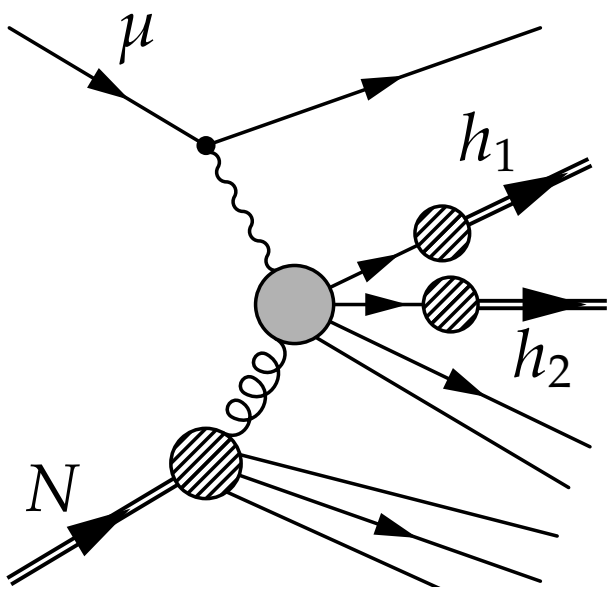
$$\frac{\Delta G}{G} = -0.57 \pm 0.41_{\text{stat}} \pm 0.17_{\text{syst}}$$

$$x_g \approx 0.15$$

$$\mu^2 \approx 13\,\text{GeV}^2/c^2$$

est. for 2002–2006: $\delta_{\text{stat}} = 0.28$

Accessing the Gluon Polarization: High p_T

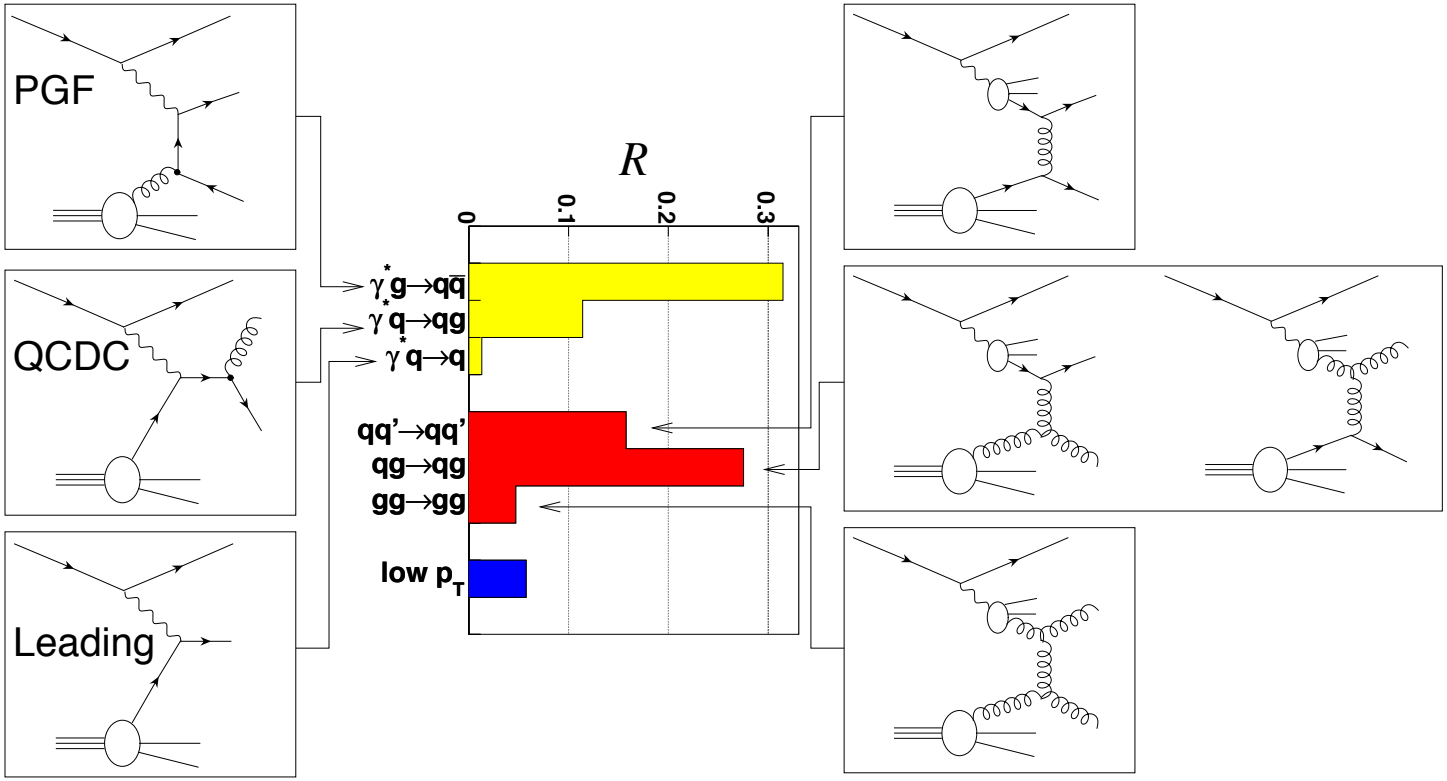


- selection
  - $p_{T,i} > 0.7\,\mathrm{GeV}/c$
  - $\sum p_T^2 > 2.5(\mathrm{GeV}/c)^2$
  - either $Q^2 < 1\,\mathrm{GeV}^2/c^2$
    or $Q^2 > 1\,\mathrm{GeV}^2/c^2$
- Monte Carlo simulation necessary for
  - fraction of photon–gluon fusion R_{PGF}
  - background asymmetries
  - analyzing power

Extraction Formula (simplified wrt. event weighting)

$$A_{\mathrm{exp}} = \frac{N^{\Rightarrow} - N^{\Leftarrow}}{N^{\Rightarrow} + N^{\Leftarrow}} = f P_{\mathrm{beam}} P_{\mathrm{target}} \langle a_{LL} \rangle R_{PGF} \frac{\Delta G}{G} + A_{\mathrm{bk}}$$

High p_T, $Q^2 < 1\,\mathrm{GeV}^2/c^2$: R_{PGF}



- PYTHIA simulation including resolved photon processes
- polarized photon PDF unknown, using positive and negative saturation to estimate uncertainty
- $R_{PGF} = 0.32$

High p_T, $Q^2 < 1\,\mathrm{GeV}^2/c^2$: Result

Systematic Error

asymmetry extraction	0.014
Monte Carlo tuning	0.052
resolved photon PDF	0.013

Result (preliminary)

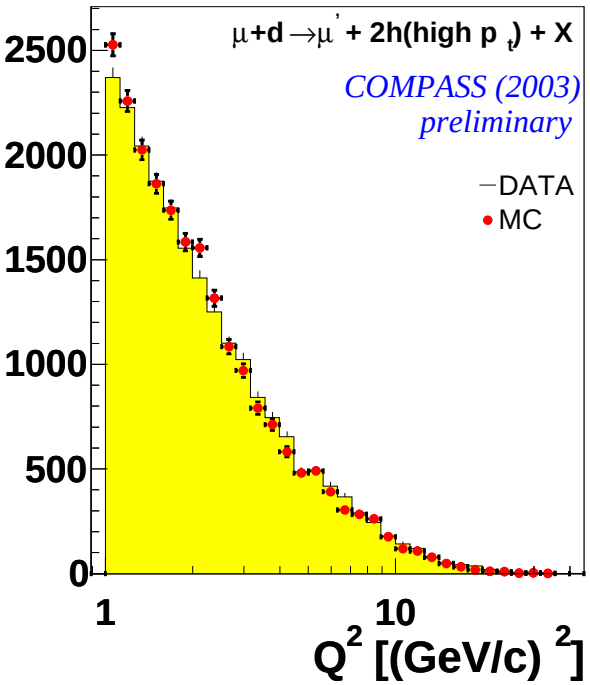
$$\frac{\Delta G}{G} = 0.016 \pm 0.058_{\mathrm{stat}} \pm 0.055_{\mathrm{syst}}$$

$$x_g \approx 0.085$$

$$\mu^2 \approx 3\,\mathrm{GeV}^2/c^2$$

est. for 2002–2006: $\delta_{\mathrm{stat}} = 0.045$

High p_T, $Q^2 > 1\,\mathrm{GeV}^2/c^2$

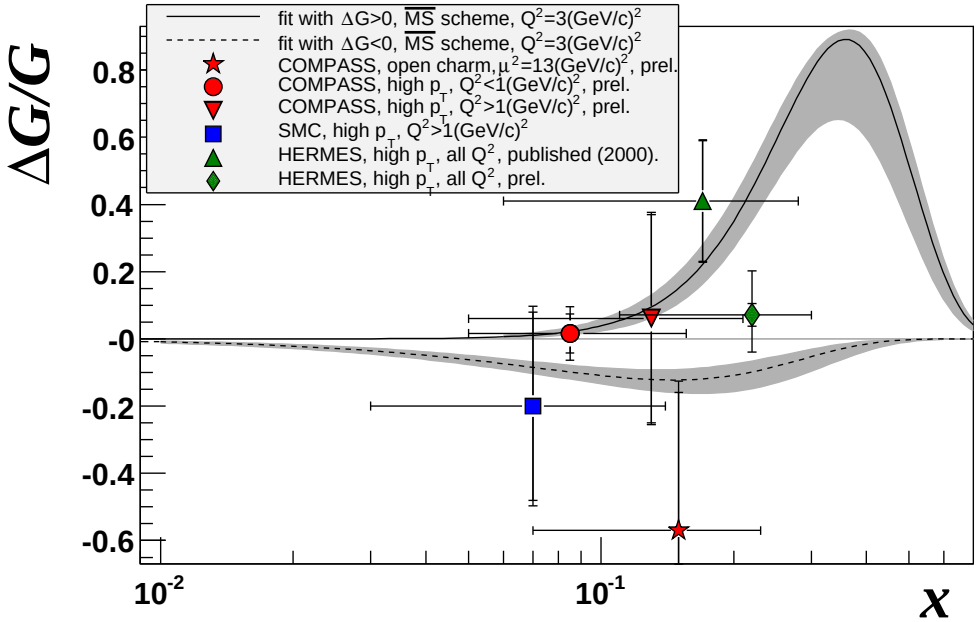


- resolved photon effects negligible
- MC using LEPTO+RADGEN
- $R_{PGF} = 0.34 \pm 0.07$
- new analysis with considerable improvement under way, using better cuts and full statistics (est. for 2002–2006: $\delta_{\mathrm{stat}} = 0.14$)

Result (preliminary, 2002–2003 only)

$$\frac{\Delta G}{G} = 0.06 \pm 0.31_{\mathrm{stat}} \pm 0.06_{\mathrm{syst}} \qquad (x_g \approx 0.13, \mu^2 \approx 3\,\mathrm{GeV}^2/c^2)$$

Summary



Result

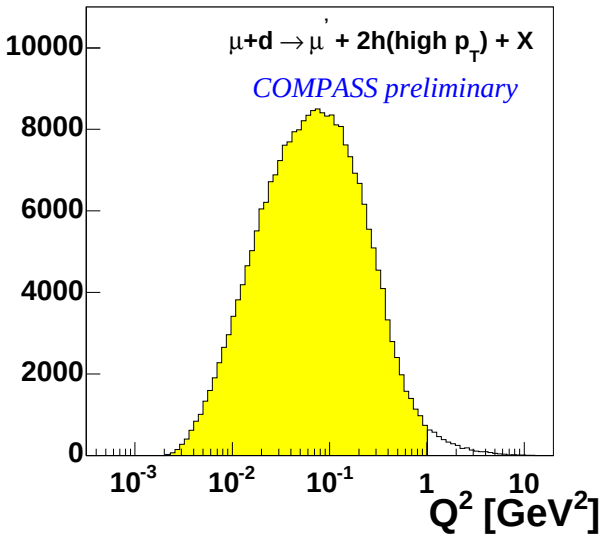
ΔG seems to be small

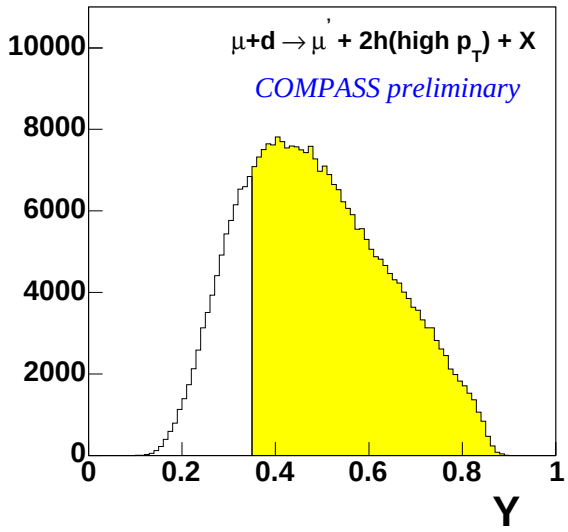
Outlook

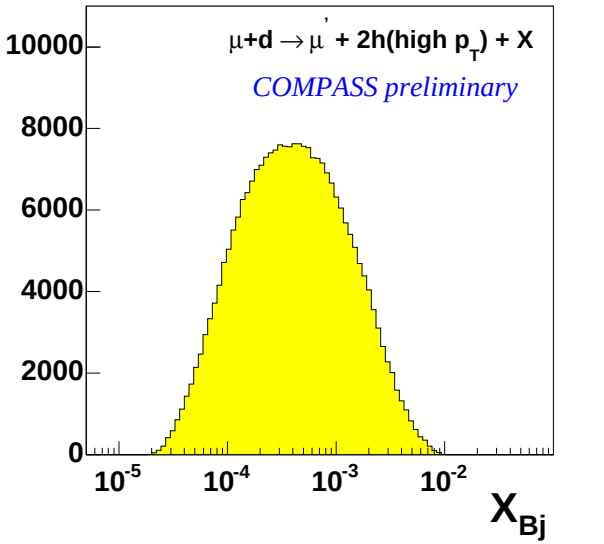
- measurement with proton target on-going this year
- 2006 data hold significant improvement in statistics
- single-inclusive high p_T hadron analysis under way

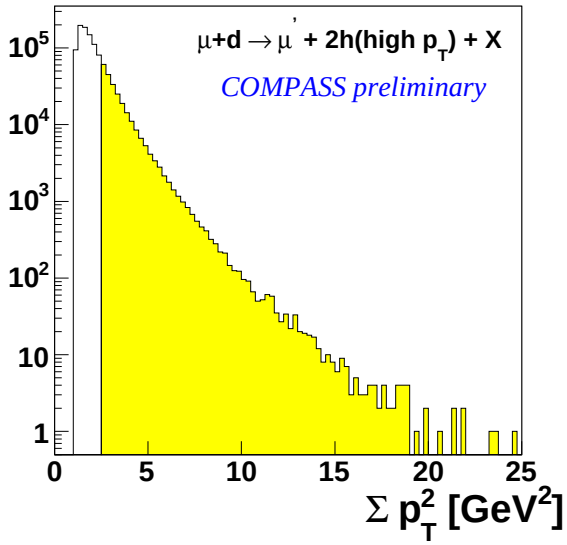
Backup Slides

High p_T, $Q^2 < 1\,\mathrm{GeV}^2/c^2$: Kinematic Distributions

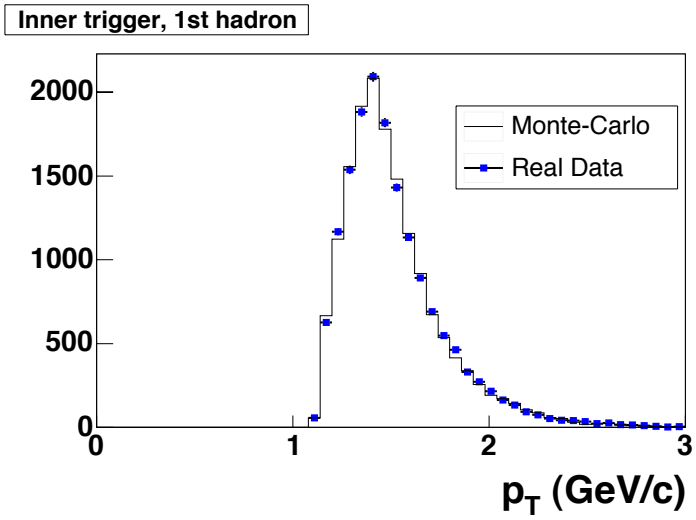


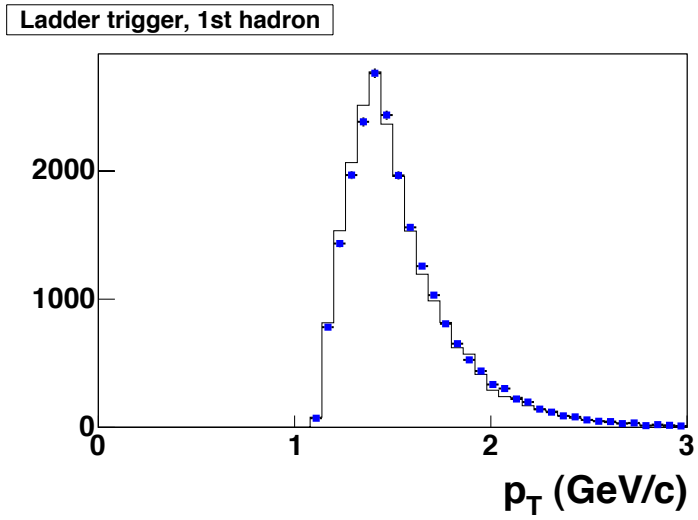


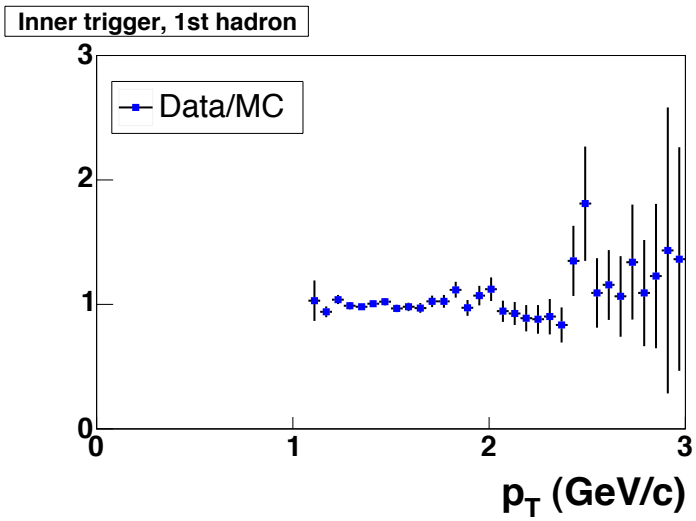


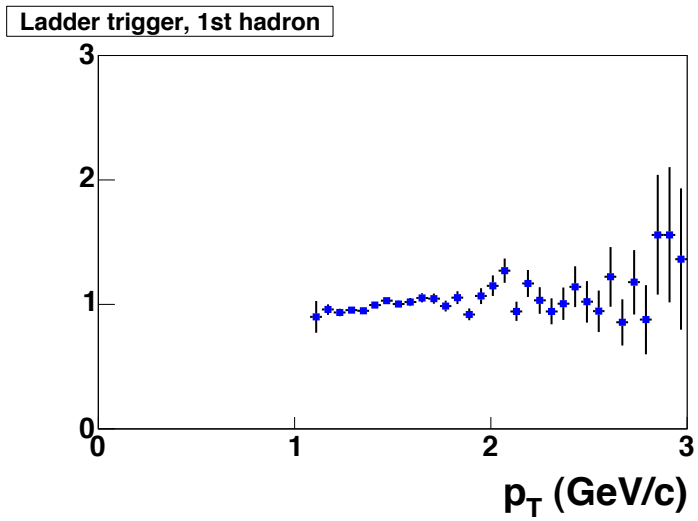


High p_T, $Q^2 < 1\,\mathrm{GeV}^2/c^2$: Data/MC for $p_{T,1}$

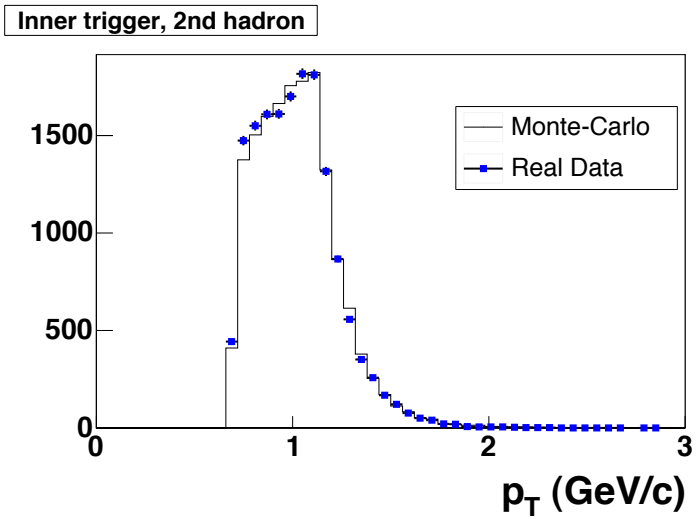


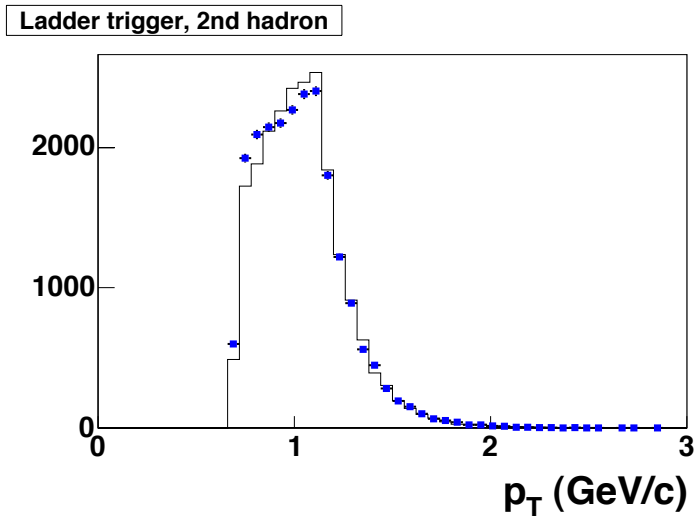


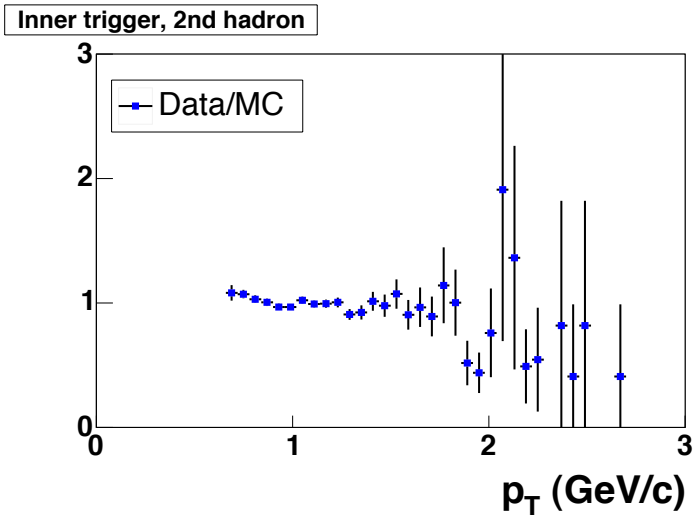


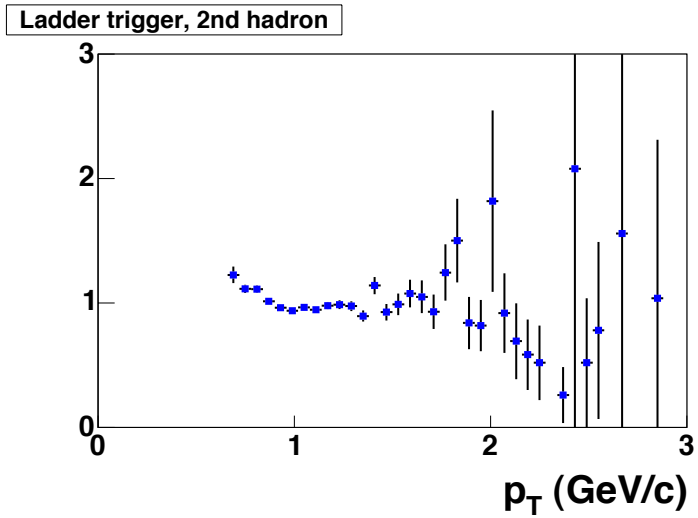


High p_T, $Q^2 < 1\,\mathrm{GeV}^2/c^2$: Data/MC for $p_{T,2}$









High p_T, $Q^2 > 1\,\mathrm{GeV}^2/c^2$: Data/MC for p