Measurement of $\frac{\Delta G}{G}$ at COMPASS

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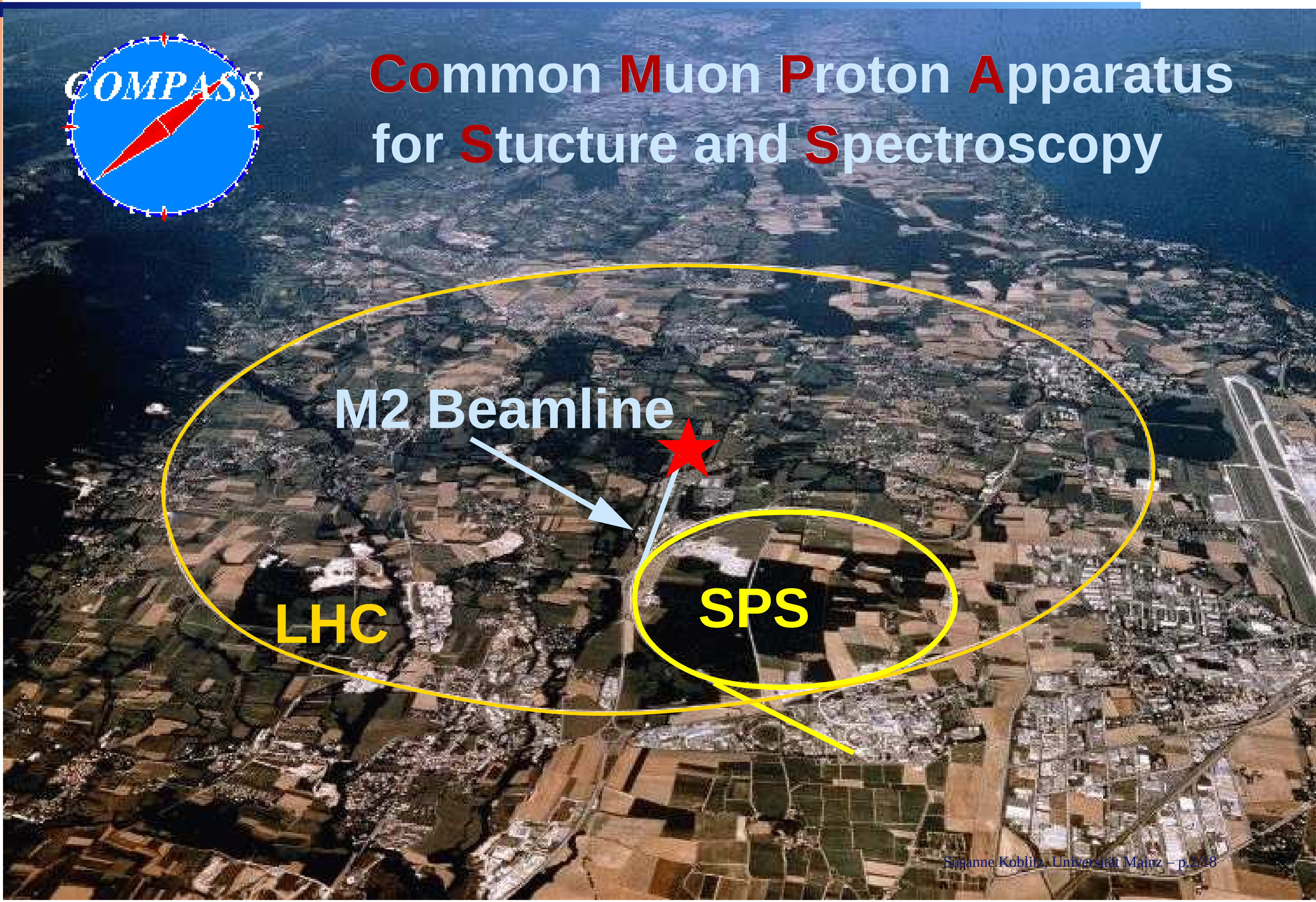
on behalf of the COMPASS Collaboration

- COMPASS Experiment
- $\frac{\Delta G}{G}$ Measurement
- Open Charm analysis
- High p_T Hadron Pairs
- Conclusion

COMPASS Experiment



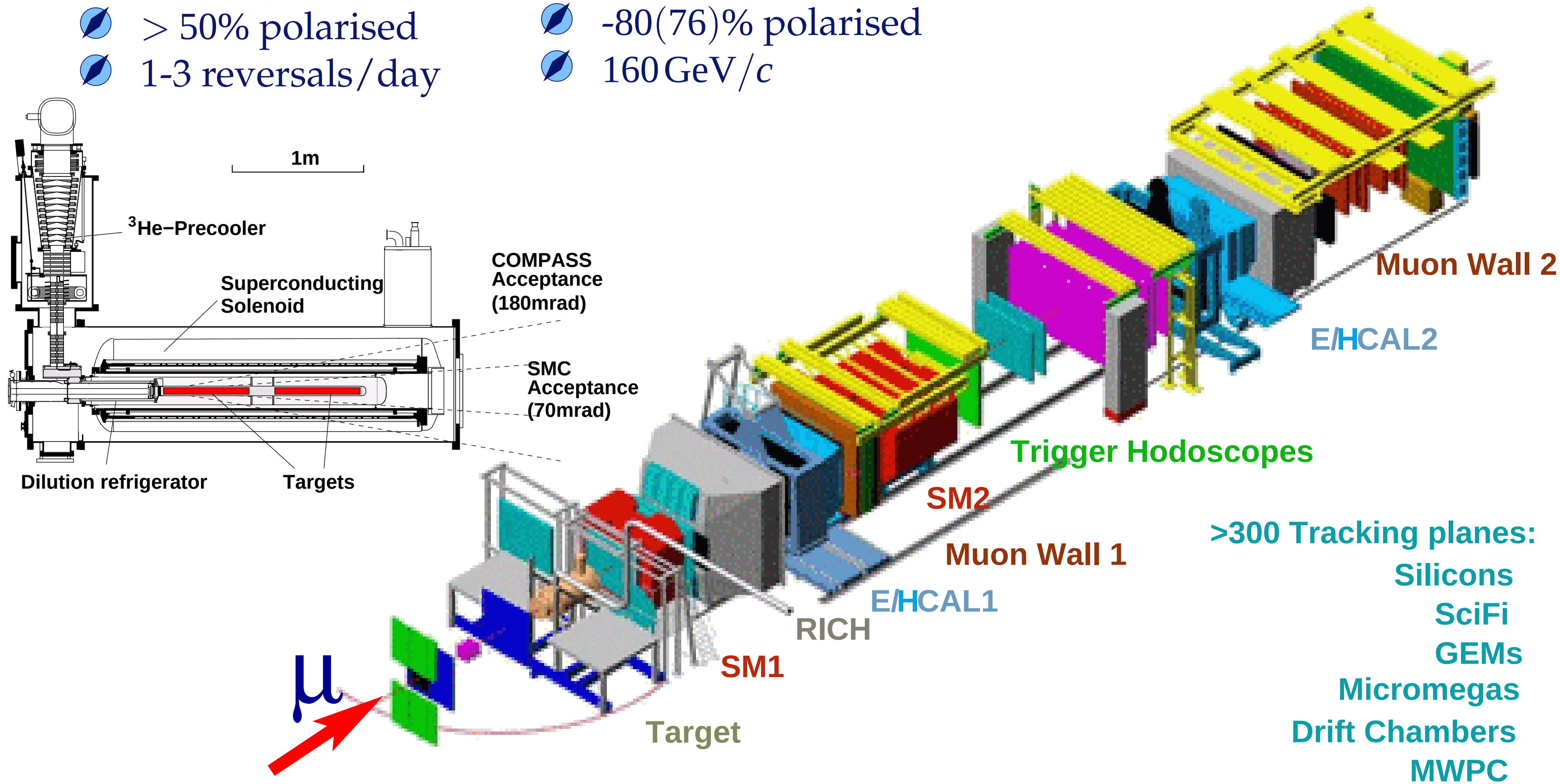
COMPASS Detector

Target:

- ^{6}LiD
- 2 cells (60 cm)
- $> 50\%$ polarised
- 1-3 reversals/day

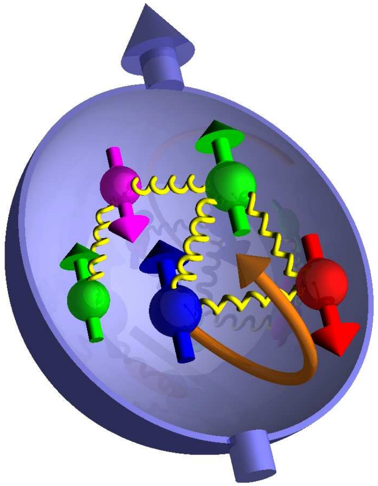
μ beam:

- $2 \cdot 10^8$ particles/spill(4.8s/16.8s)
- -80(76)% polarised
- 160 GeV/c



>300 Tracking planes:
Silicons
SciFi
GEMs
Micromegas
Drift Chambers
MWPC
Straws

Spin Structure of the Nucleon



Nucleon:

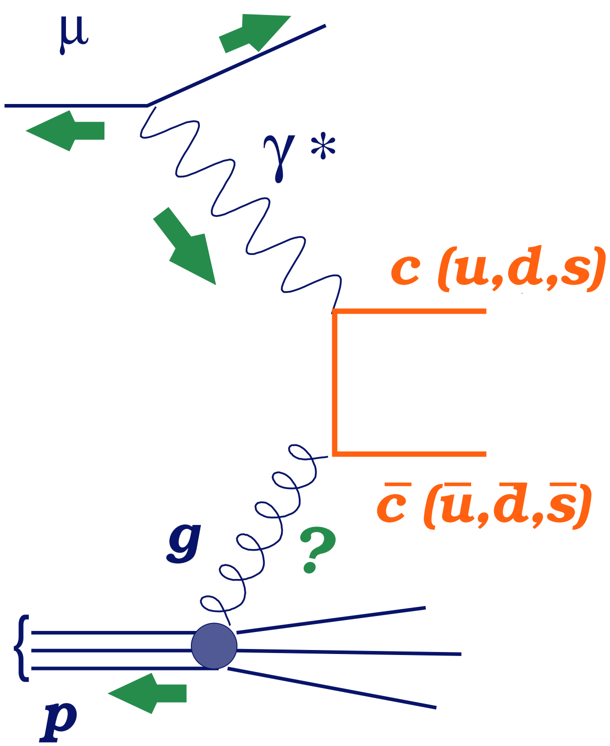
- composition: quarks, gluons
- spin: $\frac{1}{2} \rightarrow$ spin composition?

$$\boxed{< \mathbf{S_z^N} > = \mathbf{\frac{1}{2}} = \frac{1}{2}\Delta\Sigma + \Delta G + < L_Z >}$$

- quark contribution:
  - measured $\Delta\Sigma$ smaller than predicted
  - does not explain total nucleon spin
- **How about the gluon contribution?**

$\frac{\Delta G}{G}$ in COMPASS

Photon-Gluon-Fusion



PGF Tags:

- high p_T hadron pairs
  - scale: $\sum p_T^2$ or Q^2
  - event selection: 2 hadrons
  - ☺ high statistics
  - ☹ competing processes
  - ⇒ difficult systematics

- open charm
  $(\gamma^\star g) \longrightarrow (c\overline{c}) \longrightarrow D\,X \longrightarrow (K\pi)\,X$
  - scale $\mathbf{\hat{s} = 4m_c^2}$
  - ☺ no physical background
  - ☹ challenge: **c**-quark tagging
  - ⇒ low statistics

Determination of $\frac{\Delta G}{G}$

based on event rates:

$$N_{u,d} = \mathbf{a}\,\Phi\, n\,(\sigma_{PGF} + \sigma_B)(1 + P_{\mathrm{T}} P_{\mathrm{B}}\, f\,(\mathbf{a}_{LL}\,\frac{\sigma_{PGF}}{\sigma_{PGF} + \sigma_B}\,\frac{\Delta G}{G} + a^B_{LL}\,\frac{\sigma_B}{\sigma_{PGF}+\sigma_B} A_B))$$

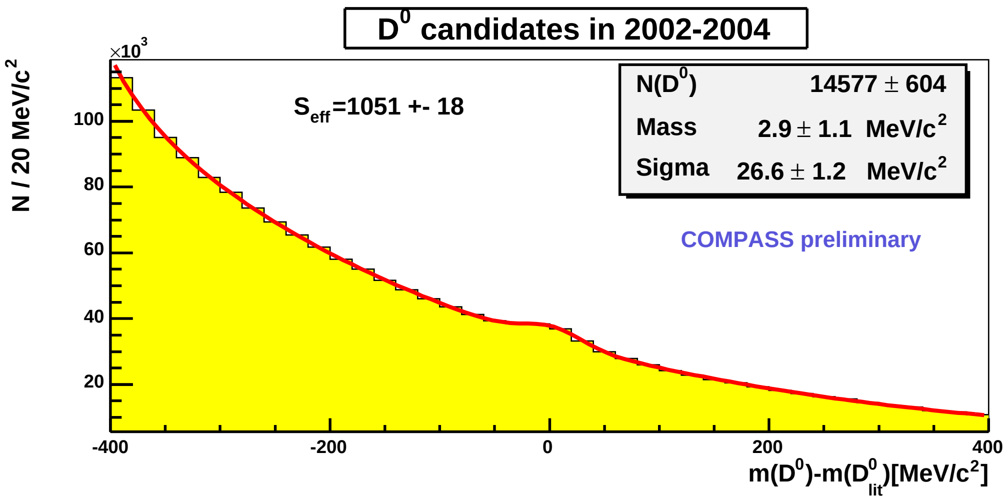
- 4 counting rates: 2 cells $\times$ 2 configurations: **double ratio:** $\delta = \frac{N_u \cdot N'_d}{N'_u \cdot N_d}$
- **flux normalisation**: same flux for both cells $\longrightarrow \frac{\Phi n_u \cdot \Phi' n_d}{\Phi' n_u \cdot \Phi n_d} = 1$
- assume: **stable acceptance** ratio: $\frac{a_u \cdot a'_d}{a_d \cdot a'_u} = 1$
- assume **$\mathbf{A}_B$ negligible**

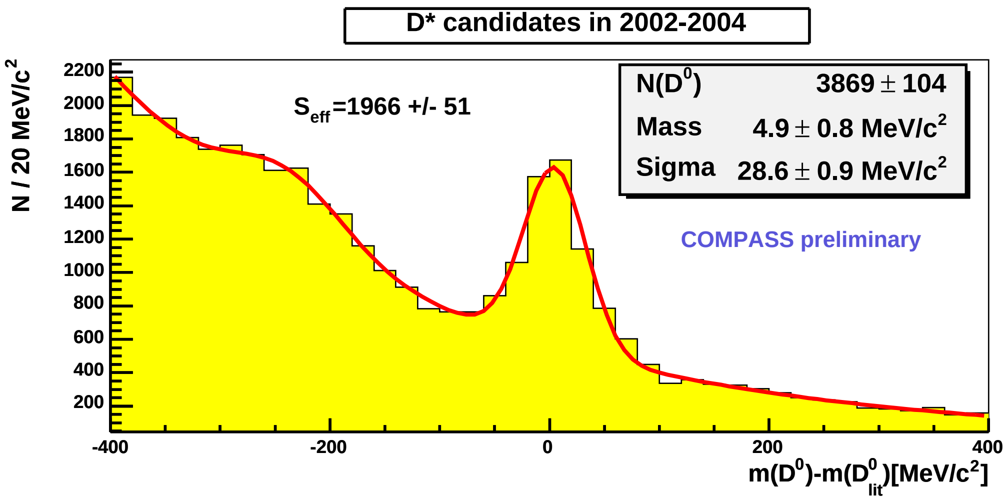
$\Rightarrow$ solve for $\frac{\Delta G}{G}$ (2nd order equation)

- needs: P_{T} ✓, P_{B} ✓, f ✓, analysing power a_{LL} & signal purity $\frac{\sigma_{PGF}}{\sigma_{PGF}+\sigma_B}$
- **open charm:** evaluated event by event
- **high p_T :** average for full data sample

D Meson Reconstruction

- open charm tag: **reconstructed D-mesons**



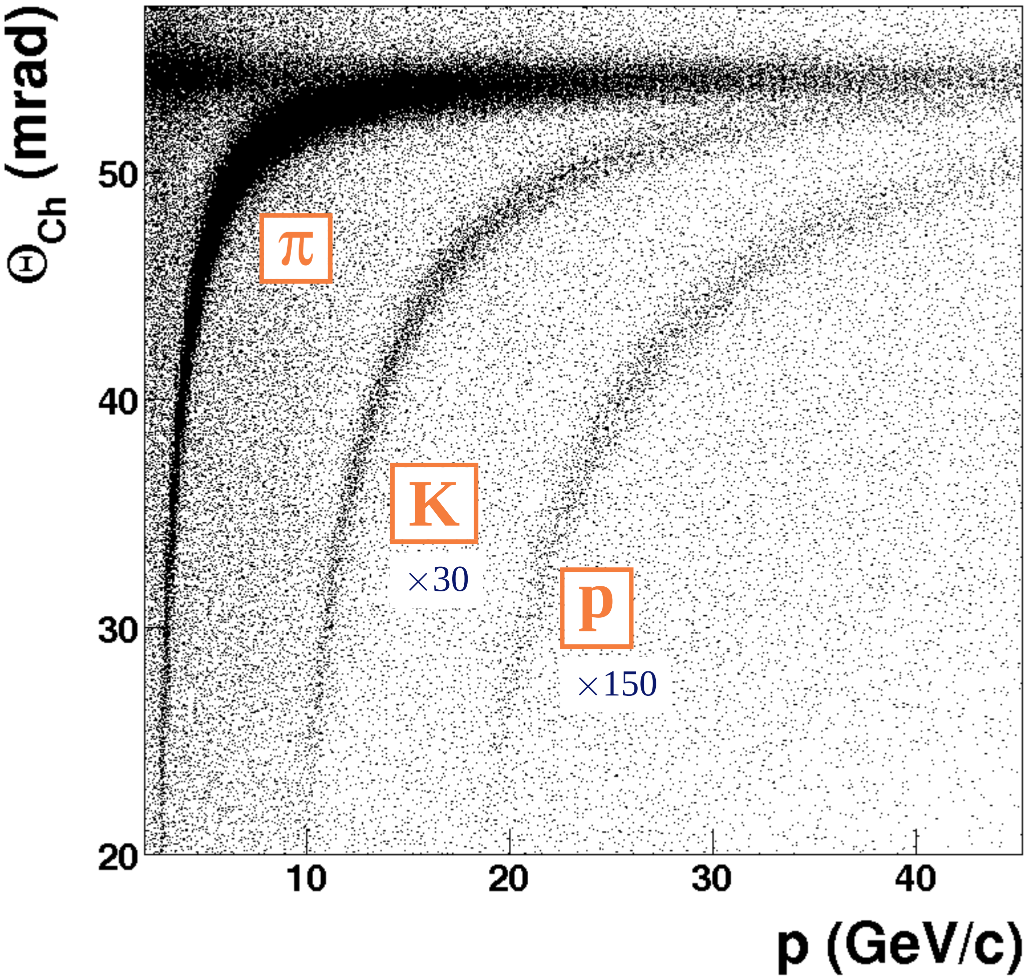


- thick target: no decay vertex
- track based reconstruction
- two channels:
  - $D^0 \to (K\pi)$, **no $D^\star$ tag**
  - $D^\star \to (K\pi)\pi_{slow}$
- **selection criteria:**
  - **D^0 kinematics:**
    - momentum fraction $z_{D^0} > 0.2(0.25)$
    - D^0 decay angle: $|cos\theta^\star| < 0.85(0.5)$
  - **$D^\star$ tag:** mass difference δm

    $3.1\,\mathrm{MeV}/c^2 < \delta m - m_\pi < 9.1\,\mathrm{MeV}/c^2$
  - **PID** (next slide)

Particle Identification in the RICH

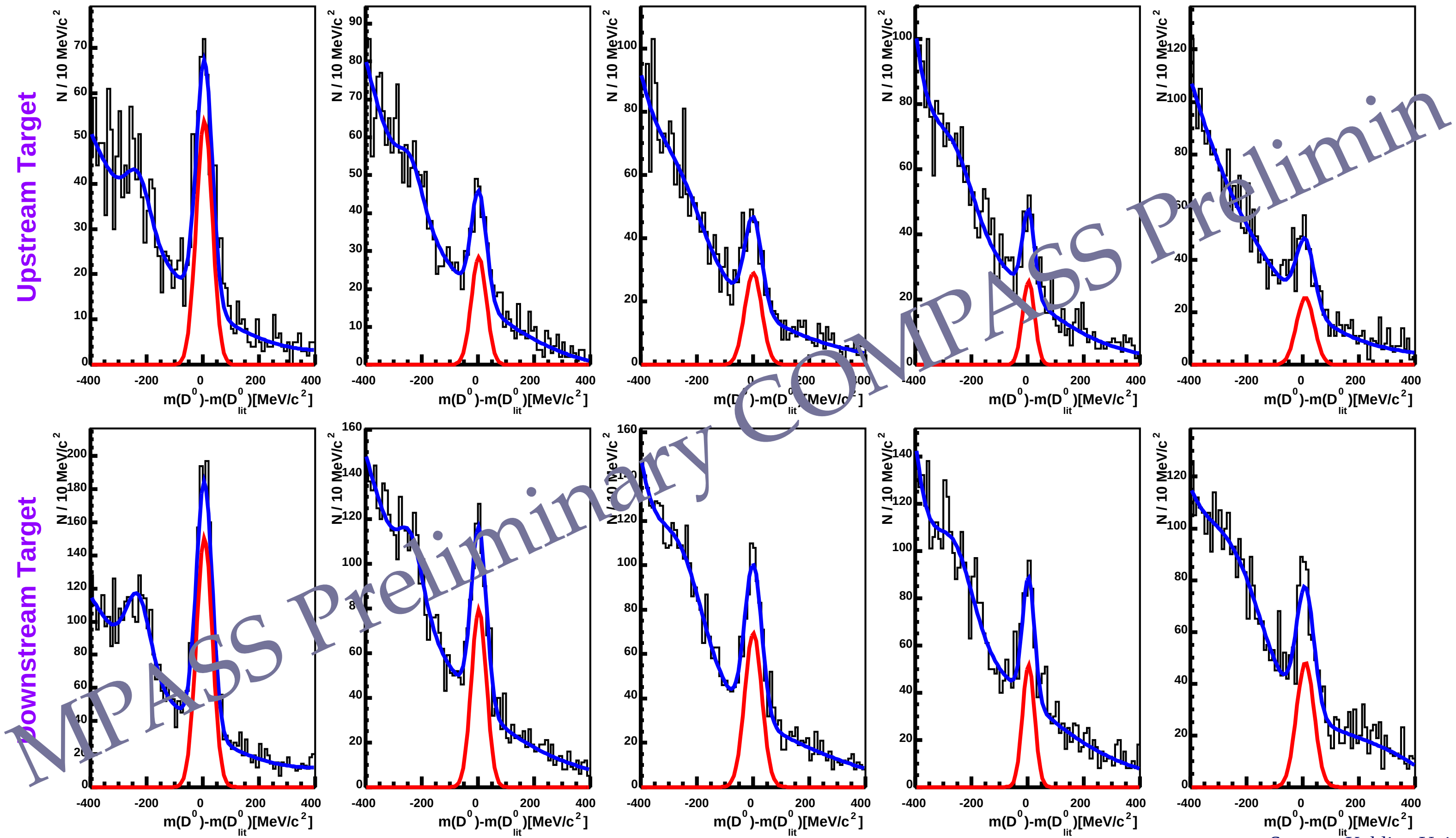
- RICH: K/π separation up to $\sim 50\,\mathrm{GeV}/c$
- for D-mesons:
  - **kaon** identification
  - **pion:** kaon exclusion
- new method applied
  $\longrightarrow$ **log-likelihood**
- $\oplus$ background parametrisation
- $\oplus$ number of photons in ring



Signal Purity

- signal purity: $\frac{S}{S+B}$ taken from fit to spectra
- analysing power $\leftrightarrow$ signal purity anticorrelated
  $\Rightarrow$ **subdivide sample into bins of a_{LL} for fit**

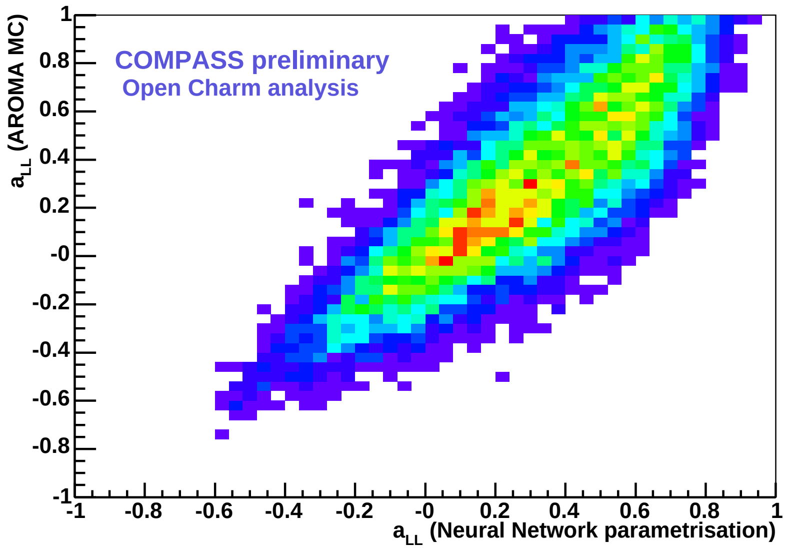
Example of fit to spectra of $D^{\star}$ candidates (**COMPASS Preliminary**)



Analysing Power

PGF events: $\frac{A_{||}}{D} = \frac{\int d\hat{s} \Delta\sigma^{PGF}(\hat{s}) \Delta G(x_g, \hat{s})}{\int d\hat{s} \sigma^{PGF}(\hat{s}) G(x_g, \hat{s})} \approx < a_{LL} > \frac{\Delta G}{G}$

D: Depolarisation factor



- hard scattering kinematics
- needs MC information
- calculated from: y, Q^2, s, t, u
- MC (AROMA) vs Data: ✓

Open Charm:

- **a**$_{LL}$ from **observables?** ⇒ **neural network**
- parametrisation with: y, Q^2, z_{D^0}, $p^{\gamma}_{T\,D^0}$

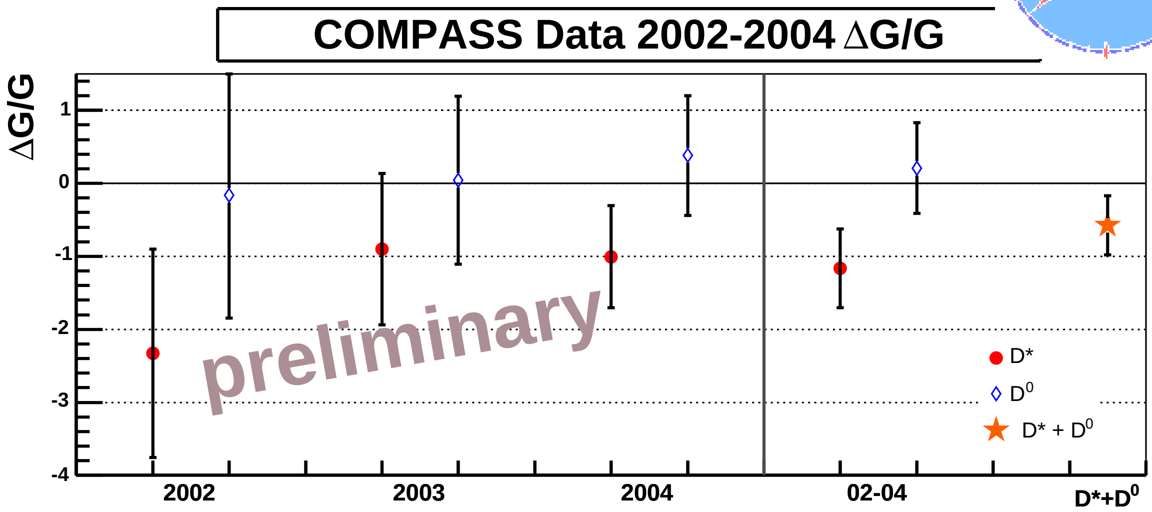
$\frac{\Delta G}{G}$ from Open Charm (preliminary)

$\frac{\Delta G}{G}$ Determination:

- use weighted events

$$\mathbf{w} = f\,P_{\mathrm{B}}\,a_{LL}\,\frac{S}{S+B}$$

$\Rightarrow$ optimises σ_{stat}



- calculate $\frac{\Delta G}{G}$ for each single year/channel $\Rightarrow$minimises σ_{syst}

Preliminary Result from COMPASS 2002-2004 data

$$\boxed{\frac{\Delta G}{G} = -0.57 \pm 0.41}$$

$\mu^2 \sim 13\,(\mathrm{GeV}/c)^2$, $x_G \sim 0.15$

Systematics

- **False Asymmetry:** non physical asymmetry
  from unstable acceptance: $\frac{a_u \cdot a'_d}{a_d \cdot a'_u} \neq 1$
- studied possible FAs from instabilities (in full mass range)

  no effect seen! up to the level of statistical error

$\rightarrow$ **contribution estimated from statistical precision**

$$\delta\left(\frac{\Delta G}{G}\right)_{\mathrm{FA}} = 0.10$$

- **Fit to Mass Spectra:** results used for signal purity
- many choices for fit: (background function, minimization, binning, ...)
- for systematics: perform different fits $\rightarrow$ look at spread of $\frac{\Delta G}{G}$

$\rightarrow$ **contribution from fitting procedure**

$$\delta\left(\frac{\Delta G}{G}\right)_{\mathrm{fit}} = 0.09$$

Systematics (2)

- background asymmetry:
  - no evidence found!(looser cuts, sidebands ...)
  - estimate effect: free parameter in $\frac{\Delta G}{G}$ evaluation

$$\delta(\Delta G/G)_{\mathrm{BA}} = 0.07$$

- Monte Carlo: model dependency checked with:
  - different charm masses
  - different structure functions

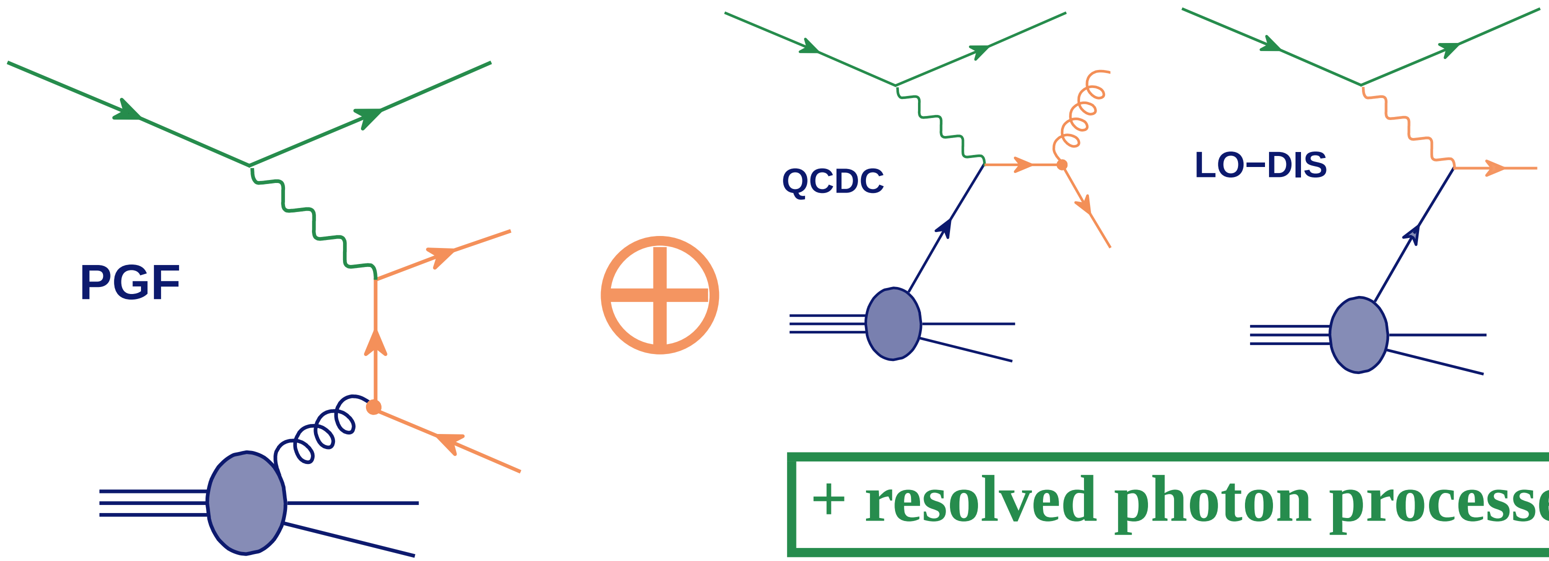
$$\delta(\Delta G/G)_{\mathrm{MC}} = 0.05$$

- binning procedure: $\delta(\Delta G/G)_{\mathrm{MC}} = 0.04$
- target polarisation (5%): $\delta(\Delta G/G)_{\mathrm{TP}} = 0.03$
- beam polarisation (5%): $\delta(\Delta G/G)_{\mathrm{BP}} = 0.03$
- dilution factor (5%): $\delta(\Delta G/G)_{\mathrm{DF}} = 0.03$

$$\boxed{\frac{\Delta G}{G} = -0.57 \pm 0.41\,(\mathrm{stat}) \pm 0.17\,(\mathrm{syst})}$$

$\mu^2 \sim 13\,(\mathrm{GeV}/c)^2$ and $x_G \sim 0.15$

High p_T Analysis



+ resolved photon processes

- more physics background: Monte Carlo for **signal purity** and $< a_{LL} >$
- 2 separate analysis:

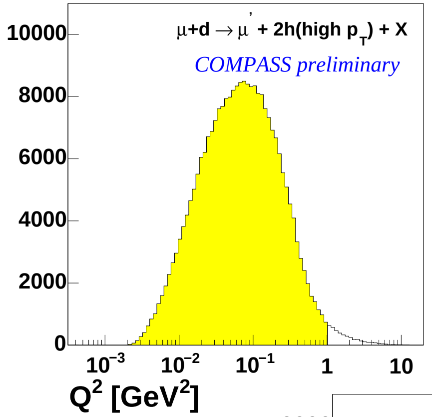
$Q^2 > 1\,\mathrm{GeV}^2$:

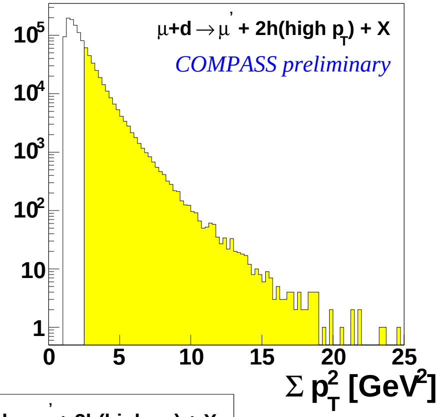
- Monte Carlo: LEPTO
- ☺ no resolved photons
- ☹ low statistics

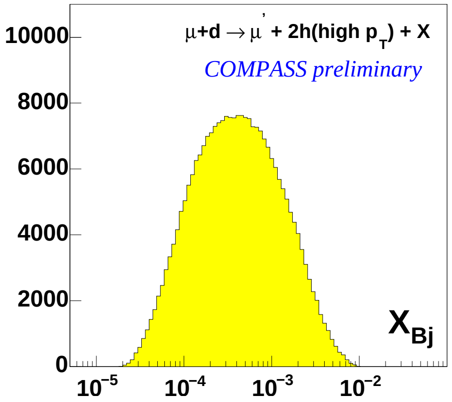
$Q^2 < 1\,\mathrm{GeV}^2$:

- Monte Carlo: PYTHIA
- ☹ resolved photon background
- ☺ large statistics

Data and Monte Carlo



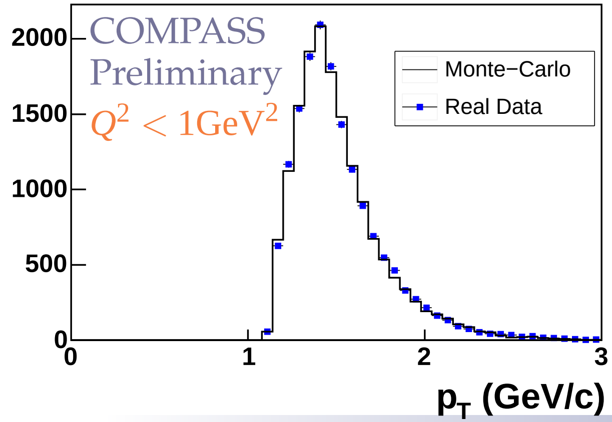


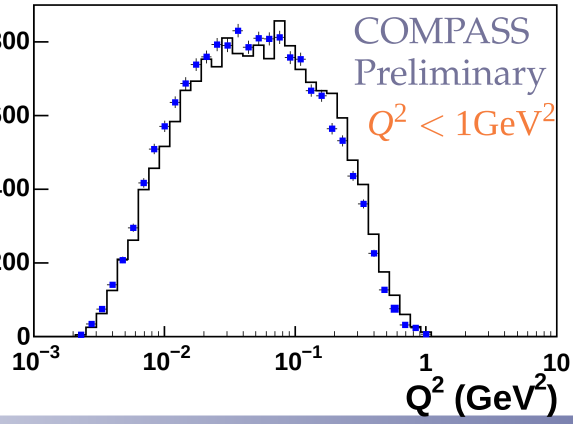


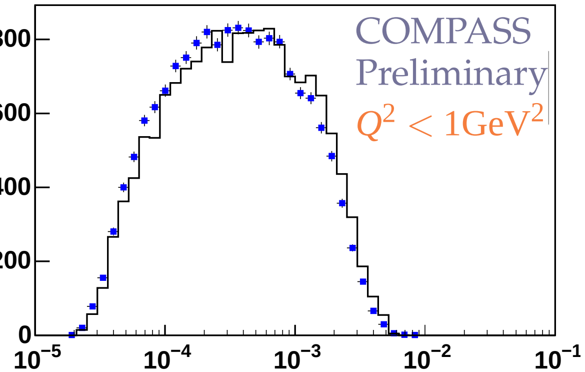
Event Selection:

- high p_T : $p_{T,1}, p_{T,2} > 0.7\,\mathrm{GeV}/c$
- $\sum p_T$: (Scale)
  $p_{T,1}^2 + p_{T,2}^2 > 2.5\,(\mathrm{GeV}/c)^2$
- current fragmentation:
  $x_F > 0.1$ and $z > 0.1$
- event kinematics:
  $0.1 < y < 0.9$
  $x < 0.05$ (⟵ background asymmetry)
- $Q^2 < 1\,\mathrm{GeV}^2$:
  500k events selected in 2002-2004

Comparison: Data – Monte Carlo







High p_T : Results

- **Signal Purity:** $R_{\mathrm{PGF}} \sim 30\%$ (determined from MC sample)
- **low Q^2 sample:**
  - resolved photon contribution $\sim$ 50%
  - quark polarisation in photon unknown!

  $\Rightarrow$ estimated contribution from maximal and minimal polarisation
- Preliminary Results for **low Q^2: 2002+2003+2004 DATA**

$$\frac{\Delta G}{G} = 0.016 \pm 0.058\,(\mathrm{stat}) \pm 0.055\,(\mathrm{syst})$$

$$x_G \sim 0.085 \text{ and } \mu^2 = 3\,(\mathrm{GeV}/c)^2$$

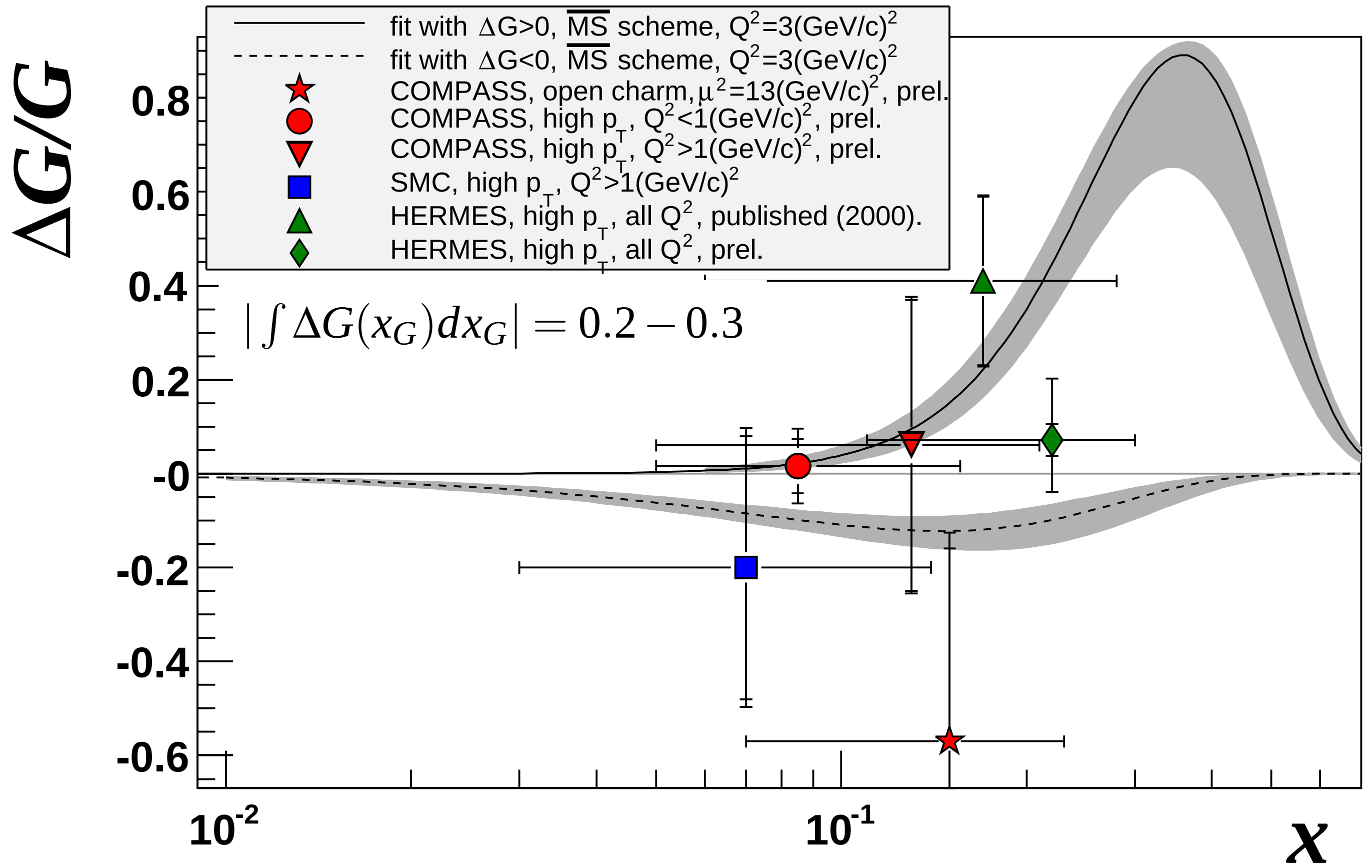
- Preliminary Results for high Q^2:(2002+2003 DATA)

$$\frac{\Delta G}{G} = 0.06 \pm 0.31\,(\mathrm{stat}) \pm 0.06\,(\mathrm{syst})$$

$$x_G \sim 0.13 \text{ and } \mu^2 = 3\,(\mathrm{GeV}/c)^2$$

- systematics:
  - **Monte Carlo uncertainties outweigh experimental systematics**
  - no false asymmetries seen $\rightarrow$ contribution estimated from statistical precision

Conclusion



- small $\int \Delta G dx_G$ prefered
- spin puzzle not yet solved!

Prospects

- Open Charm: 2002-2004 data well understood
- ☺ systematical uncertainty relatively small
- improving method: optimise event weighting & selection
- High p_T Hadron Pairs: work ongoing to optimise event selection
- 2006 data: analysis started
- ☺ improvements from hardware upgrades:
  - larger acceptance: magnet + tracking
  - RICH upgrade: improved background reduction
- ☺ in both channels significant improvement of statistics expected:

$$\delta(\Delta G/G)_{\text{high}\,p_T}\,(Q^2 < 1\,\text{GeV}^2) = 0.14$$

$$\delta(\Delta G/G)_{\text{high}\,p_T}\,(Q^2 > 1\,\text{GeV}^2) = 0.045$$

$$\delta(\Delta G/G)_{\text{OpenCharm}} = 0.28$$

...assuming beam(2006)/beam(2004)=0.88