# RESULTS ON ΔG FROM

# EXPERIMENT @ CERN

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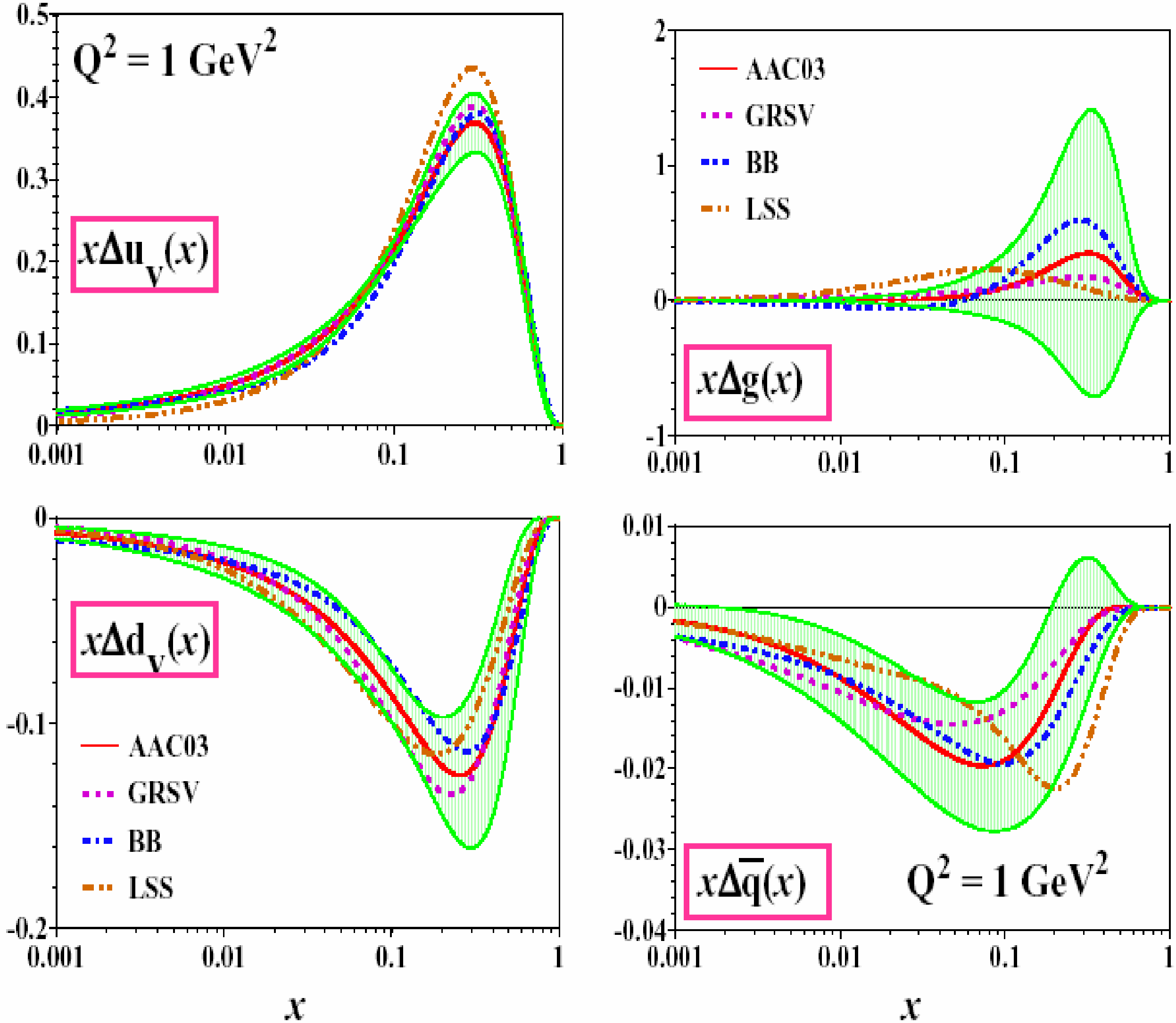
On befalf of COMPASS Collaboration

# ΔG from QCD fits to $g_1$ is badly determined

*AAC2004: M. Hirai, S. Kumano and N. Saito, Phys.Rev.D (2004)*




**NLO fits:**

*Glück, Reya, Stratmann, Vogelsang*
*Blümlein, Böttcher*
*Leader, Sidorov, Stamenov*

Hirai, Kumano, Saito:

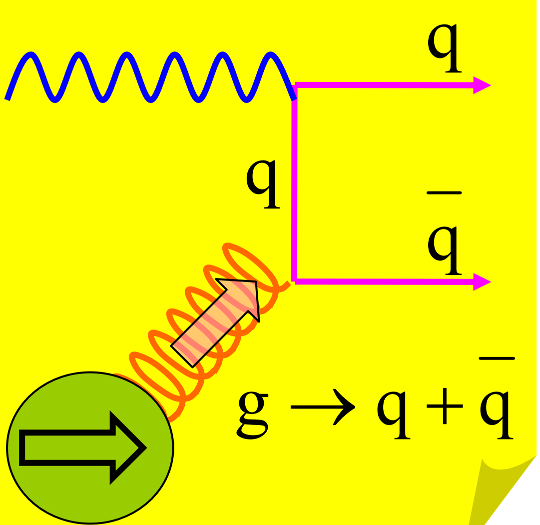
**ΔG = 0.449 ± 1.266**

**Large uncertainty**

**Use processes where ΔG is probed directly**

# ΔG from Photon-Gluon Fusion (PGF)

**Enhance the contribution to the final state from:**




**1)**

- $u, (\bar{d}, \bar{s}) \to h^+$
- $\bar{u}, (d, s) \to h^-$

**Large $p_t$ hadrons**

**Hard scale set by $p_t$**

- Large statistics, but ...
- Large background from other processes
- Theoretical uncertainties

**2)**

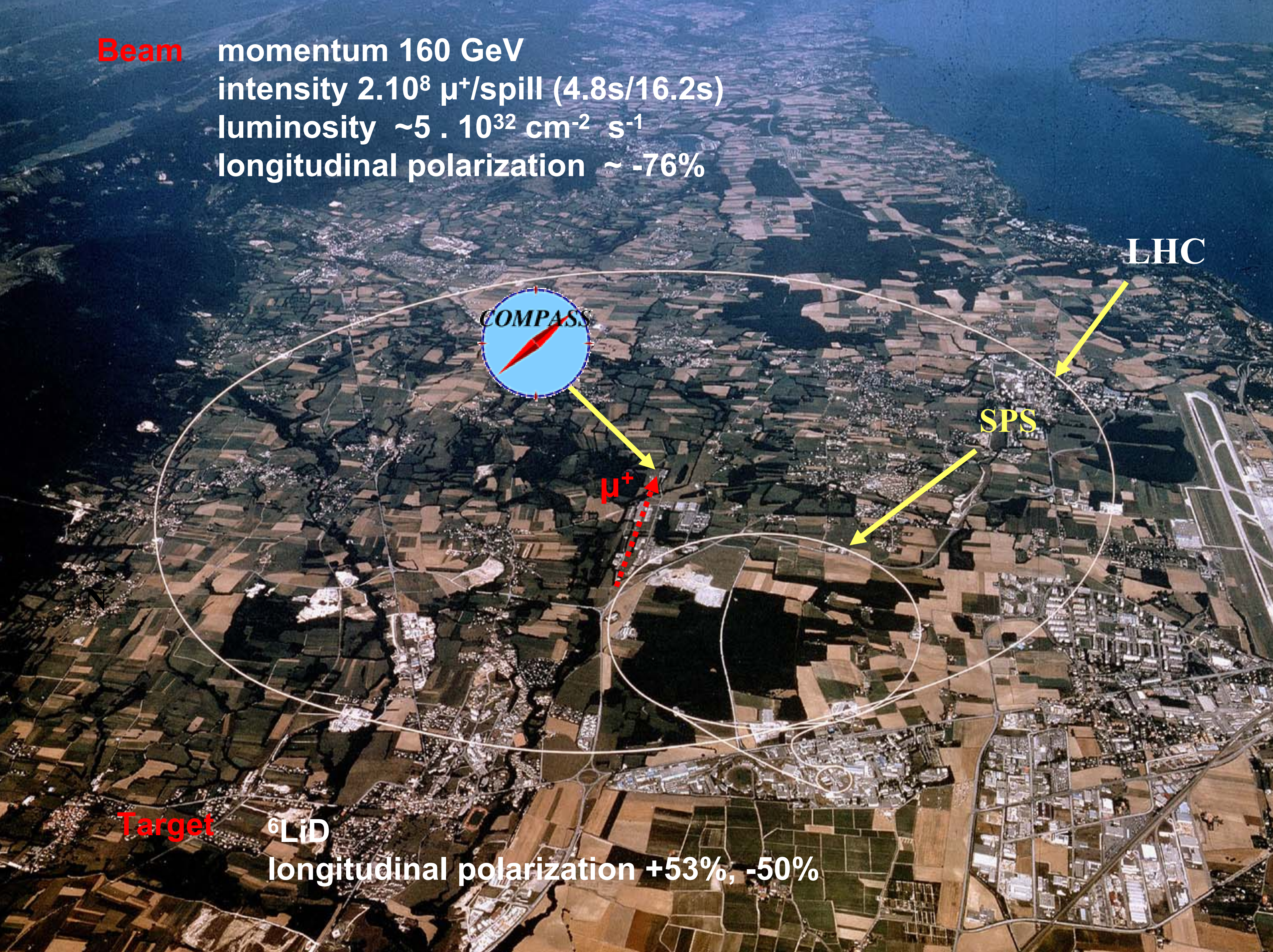
- $c \to D^0 \to K^+ \pi^-$
- $\bar{c} \to \overline{D^0} \to K^- \pi^+$
- also $D^{*\pm} \to D^0 \pi^\pm$

**Hard scale set by $m_{charm}$**

- Clean theory, but ...
- Difficult experimentaly

**USE ANY $Q^2$**

**Beam** momentum 160 GeV
intensity $2.10^8$ $\mu^+$/spill (4.8s/16.2s)
luminosity ~5 . $10^{32}$ $cm^{-2}$ $s^{-1}$
longitudinal polarization ~ -76%




**Target** $^6LiD$
longitudinal polarization +53%, -50%

**COMMON**
**MUON and**
**PROTON**
**APPARATUS for**
**STRUCTURE and**
**SPECTROSCOPY**

## THE COMPASS COLLABORATION

***Czech Republic, Finland, France, Germany, India, Israel, Italy, Japan, Poland, Portugal, Russia, Switzerland***

**Bielefeld, Bochum, Bonn, Burdwan, Calcutta, CERN, Dubna, Erlangen, Freiburg, Heidelberg, Helsinki, Lisbon, Mainz, Miyazaky, Moscow, Munich, Nagoya, Prague, Protvino, Saclay, Tel Aviv, Torino, Trieste, Warsaw**

**31 Institutes, more than 270 physicists and students**

# Data collected

| Year | Effective days @ longitudinal polarization | Integrated luminosity ($fb^{-1}$) | Analysed |
|---|---|---|---|
| 2002 | 43 | 0.45 | all |
| 2003 | 36 | 0.80 | all |
| 2004 | 54 | 1.12 | ~ 50% |

More detectors
Improved reconstruction

2005: no data taking
2006: taking data with an improved setup

# Asymmetry determination

$$A^{measured} = \frac{1}{2}\left( \frac{N_u^{\uparrow\downarrow} - N_d^{\uparrow\uparrow}}{N_u^{\uparrow\downarrow} + N_d^{\uparrow\uparrow}} + \frac{N_d^{\uparrow\downarrow} - N_u^{\uparrow\uparrow}}{N_d^{\uparrow\downarrow} + N_u^{\uparrow\uparrow}} \right)$$

Before reversal — After reversal

$$A_{\parallel} = \frac{A^{measured}}{f \cdot | P_{\mu} \cdot P_t |}$$

**TARGET**

cell *u* — cell *d*

- Opposite polarizations, $P_t \approx \pm 50\%$
- Polarization reversed
  - by field rotation every ~8 h
  - by microvawes 2-3 times/year
- Dilution factor $\langle f \rangle \approx 0.4$

**BEAM**

$\langle P_{\mu} \rangle \approx -76\%$

**DEPOLARIZATON F.**

$\langle D \rangle \approx 0.6$

**We use event-by-event weighting to optimize determination of ΔG.**

# $\Delta g(x)$ from charmed mesons:

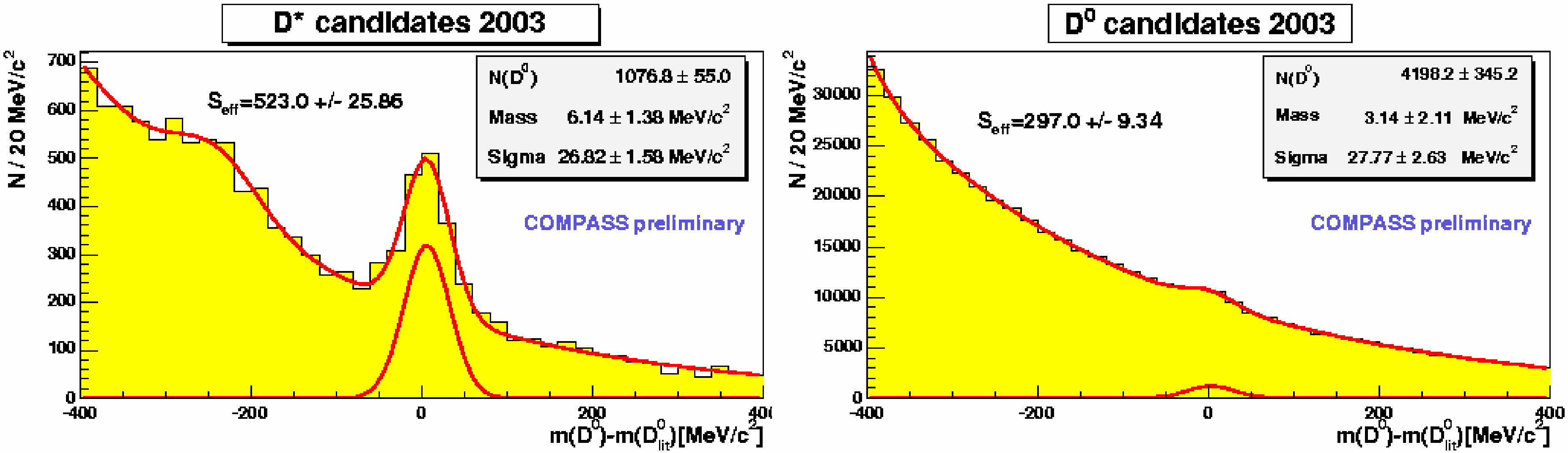
$$D^0 \rightarrow K\pi$$

$$D^* \rightarrow D^0\pi_s \rightarrow K\pi\,\pi_s$$

# Open charm ($D^0$) signal

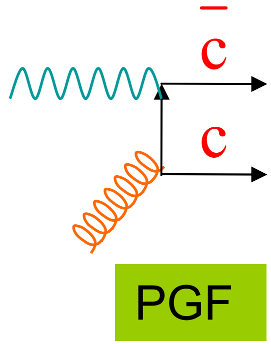
- about 30cm thick $^6$LiD target cell → No charm decay vertex reconstruction
- K/π identification in RICH important
- use $D^*$ tagging; $D^* \to D^0\pi_s \to K\pi\ \pi_s$ → Cut on $m(K\pi\pi) - m(K\pi)$.

**$m_{D0}$ with $D^*$ tagging** | **$m_{D0}$ without $D^*$ tagging**



# $\Delta g$ from $D^*$ and $D^0$

- Dominant contribution:



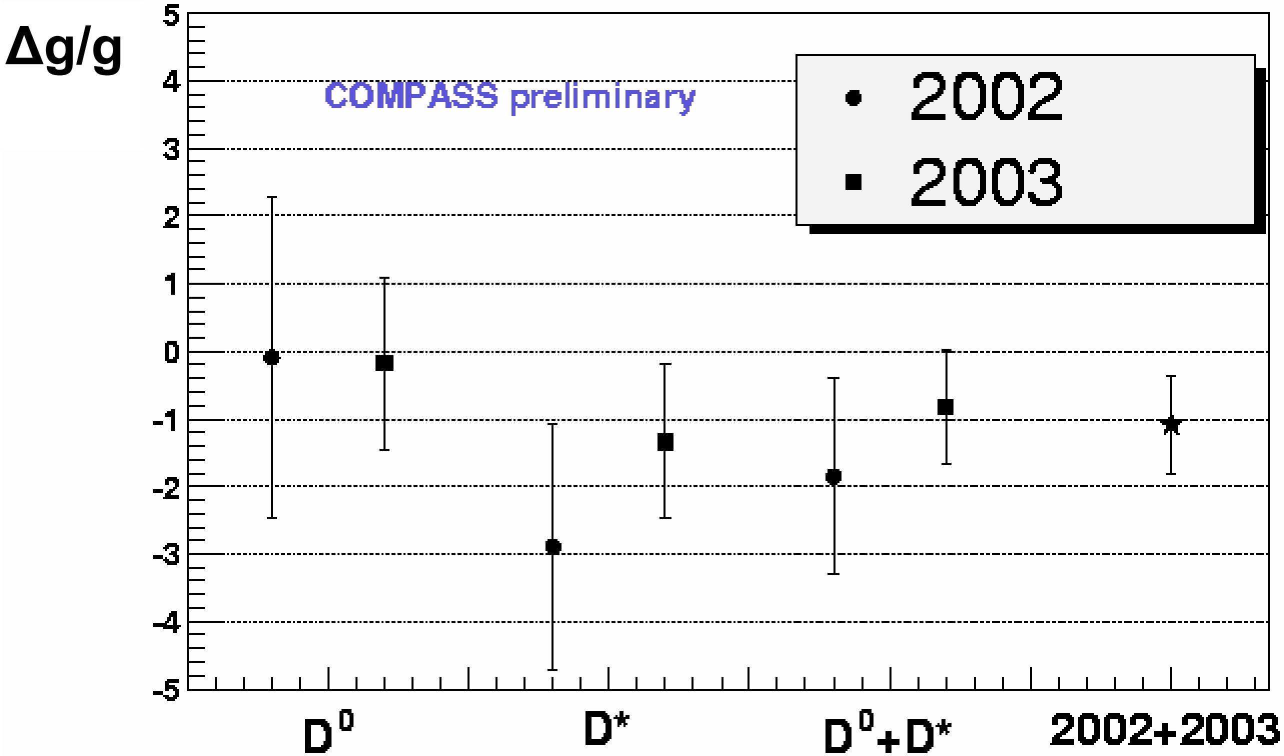

$$A_{\parallel} \approx \left\langle \hat{a}_{LL}^{\gamma g \to c\bar{c}} \right\rangle \frac{\Delta g}{g}$$

- Use event weighting to calculate $A_{\parallel}$ : $w = fP_{\mu} a_{LL} \dfrac{S}{S+B}$

**where we determined** $a_{LL}(y, p_{tD}, z_D)$ **parametrisation using the MC (Aroma)**

**and took into account correlation between** $(fP_{\mu} a_{LL})$ **and** $\dfrac{S}{S+B}$

# Δg from D* and D⁰




$$\frac{\Delta g}{g} = -1.08 \pm 0.73(stat.)$$

$$\langle \eta_g \rangle = 0.15 \pm 0.08\,(rms)$$

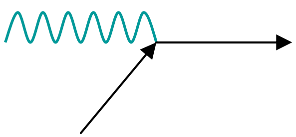
COMPASS preliminary

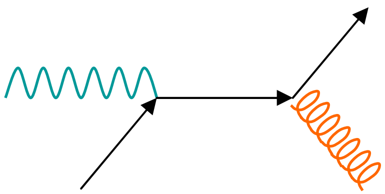
# $\Delta g(x)$ from large $p_t$ hadrons

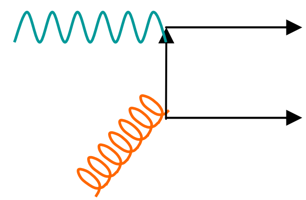
- Two hadrons at large $p_t$: $p_{t,1(2)} > 0.7$GeV, $(p_{t,1})^2 + (p_{t,2})^2 > 2.5$GeV$^2$
- Exclude resonance region: $M_{1,2} > 1.5$GeV
- Supress contribution from the target fragmentation region: $x_F$, $z > 0.1$
- Consistent LO analysis:
  - PDF,
  - $a_{LL}$,
  - parton showers OFF in JETSET.

# Contributions to the asymmetry at large $p_t$

LO **+** QCD Compton **+** PGF **+** Resolved photon processes







$$A_{\|} = R_{LP} \left\langle \hat{a}_{LL}^{\gamma q \to q} \right\rangle A_1^d + R_{QCD\text{-}C} \left\langle \hat{a}_{LL}^{\gamma q \to qg} \right\rangle A_1^d + R_{PGF} \left\langle \hat{a}_{LL}^{\gamma g \to q\bar{q}} \right\rangle \frac{\Delta g}{g} + A_{res.phot.}$$

$$R_i = \frac{\sigma_i}{\sigma_{tot}}$$

small at small x

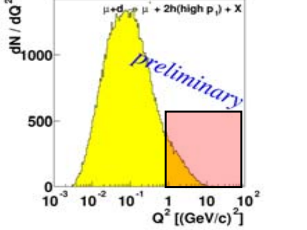
small at large $Q^2$

**$Q^2 > 1 GeV^2$ , $x < 0.05$:** **ONLY PGF** CONTRIBUTING TO THE ASYMMETRY

**$Q^2 < 1 GeV^2$:** **ALL PROCESSES** CONTRIBUTING TO THE ASYMMETRY

$Q^2$ **bigger** then 1 $GeV^2$

# Δg from large $p_t$: $Q^2 > 1$ GeV$^2$




10% of data

- **Monte Carlo (LEPTO) tuned to reproduce the data**
- **Use event weighting to calculate $A_{\parallel}$ :** $w = fDP_{\mu}$

$$\frac{A_{\parallel}}{D} = -0.015 \pm 0.089(stat.) \pm 0.013(syst.)$$

**COMPASS preliminary**

- **Only PGF contributing to the asymmetry:**

$$\frac{\Delta g}{g} = \frac{A_{\parallel}}{D} \cdot \frac{1}{\langle a_{LL}/D \rangle \cdot R_{PGF}}$$

*-0.75±0.15* *0.34±0.07* ← **From MC**

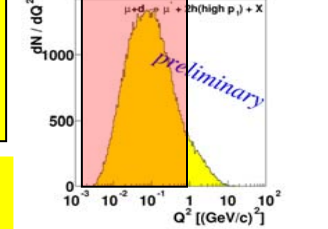
$$\frac{\Delta g}{g} = 0.06 \pm 0.31(stat.) \pm 0.06(syst.)$$

$$\langle \eta_g \rangle = 0.13 \pm 0.08\ (rms)$$

**COMPASS preliminary**

$Q^2$ **smaller then 1 GeV**$^2$

# $\Delta g$ from large $p_t$: $Q^2 < 1$ GeV$^2$

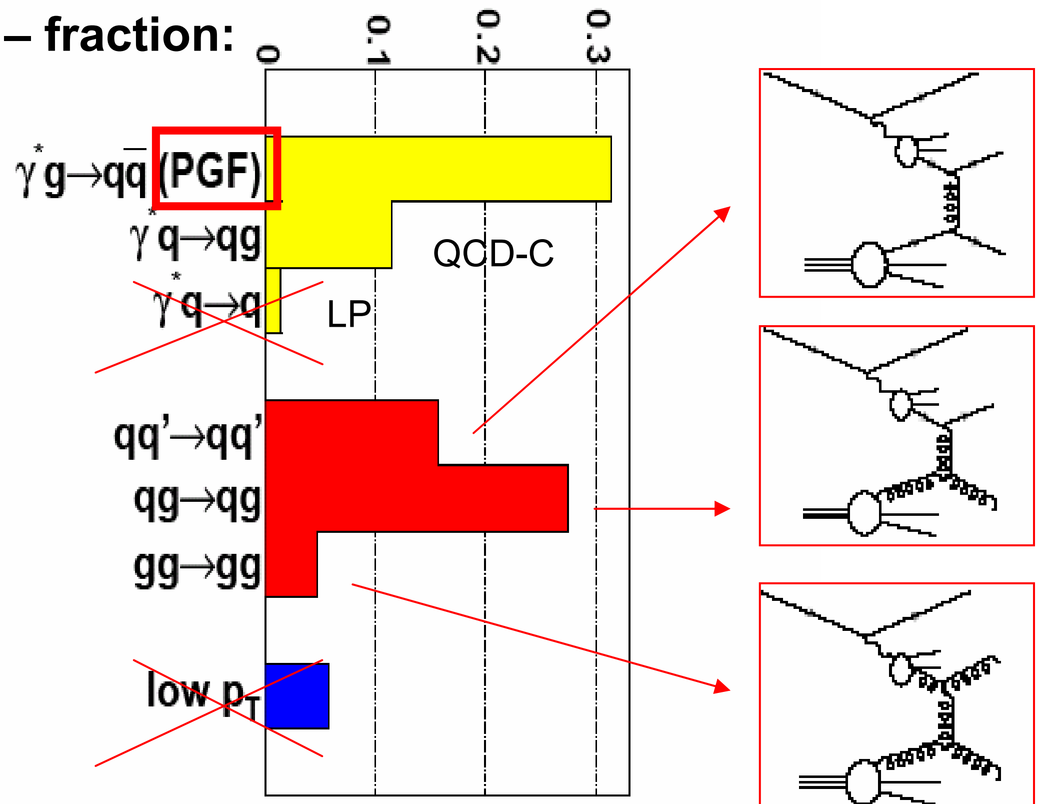



90% of data

hard | soft: resolved photon | soft: small-$p_t$

$$A_{\parallel} = R_{PGF}\cdot A_{PGF} + R_{QCD\text{-}C}\cdot A_{QCD\text{-}C} + R_{LP}\cdot A_{LP} + \sum_{f,f'=u,d,s,g,\ldots} R_{f,f'} \left\langle a_{LL}^{ff'} \frac{\Delta f^{\gamma}}{f}\frac{\Delta f'^{N}}{f'}\right\rangle + R'_{small\text{-}p_t}\cdot A_{small\text{-}p_t}$$

**R – fraction:**




- $(\Delta f'/f)^N$ : use parametrisations GRSV2000/GRV2000,
- $(\Delta f'/f)^\gamma$: assume minimal and maximal scenarios; *Gluck, Reya, Sieg, EPJ C20(2001)271*
- PYTHIA tuned to describe the data,

# $\Delta g$ from large $p_t$: $Q^2 < 1$ GeV$^2$

COMPASS preliminary

**$A_{\parallel}$**

$$\frac{A_{\parallel}}{D} = -0.002 \pm 0.019(stat.) \pm 0.003(syst.), \qquad \langle D \rangle = 0.64$$

**$\Delta g/g$**

$$\left[\frac{\Delta g}{g}(\eta_g = 0.09)\right]_{\min} = 0.016 \pm 0.068(stat.) \pm 0.011(\exp.syst.) \pm 0.018(\mathrm{MC}syst.)$$

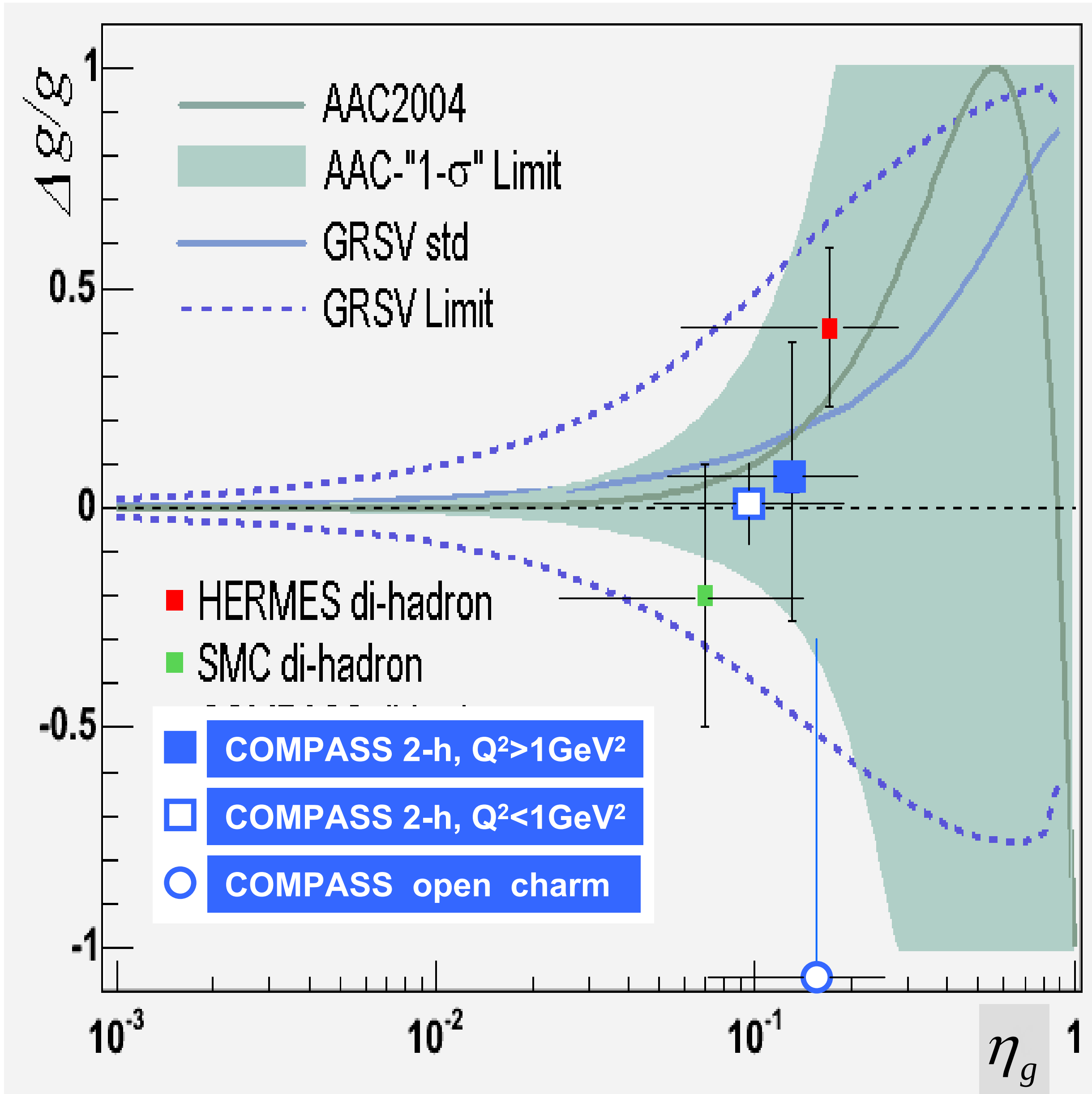
$$\left[\frac{\Delta g}{g}(\eta_g = 0.10)\right]_{\max} = 0.031 \pm 0.089(stat.) \pm 0.014(\exp.syst.) \pm 0.052(\mathrm{MC}syst.)$$

$$\frac{\Delta g}{g} = 0.024 \pm 0.089(stat.) \pm 0.057(syst.)$$

$$\langle \eta_g \rangle = 0.095^{+0.078}_{-0.040}, \qquad \mu^2 \simeq 3\,\mathrm{GeV}^2$$

assuming PYTHIA

# Results on Δg



# Conclusions

- Three independent results from COMPASS indicate that $\Delta g$ (in LO) is small at $\eta_g \approx 0.1$
- Open charm result has the smallest theoretical uncertainty but requires more data to be statisticaly significant.
- High $p_t$, small $Q^2$ result has the smallest error,

$$\Delta g / g = 0.024 \pm 0.110$$

assuming correct simulation of small $Q^2$ physics by PYTHIA.

# Outlook

- Reduction of statistical errors on $\Delta g/g$ after including 2004 data:
  - from open charm: 0.73 → 0.57,
  - from large $p_t$, $Q^2$ >1GeV$^2$: 0.31 → 0.22,
  - from large $p_t$, $Q^2$ <1GeV$^2$: 0.089 → 0.065.

- Further improvements in the analysis:
  - use Neural Networks to increase $R_{PGF}$,
  - NLO analysis.

- Resuming data taking in 2006 with improved experimental setup:
  - RICH upgrade,
  - larger acceptance of polarized target solenoid,
  - .....

# The COMPASS spectrometer