

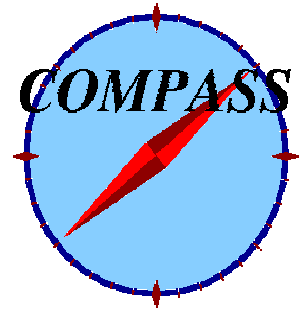
ΔS from Inclusive and Semi-inclusive Asymmetries



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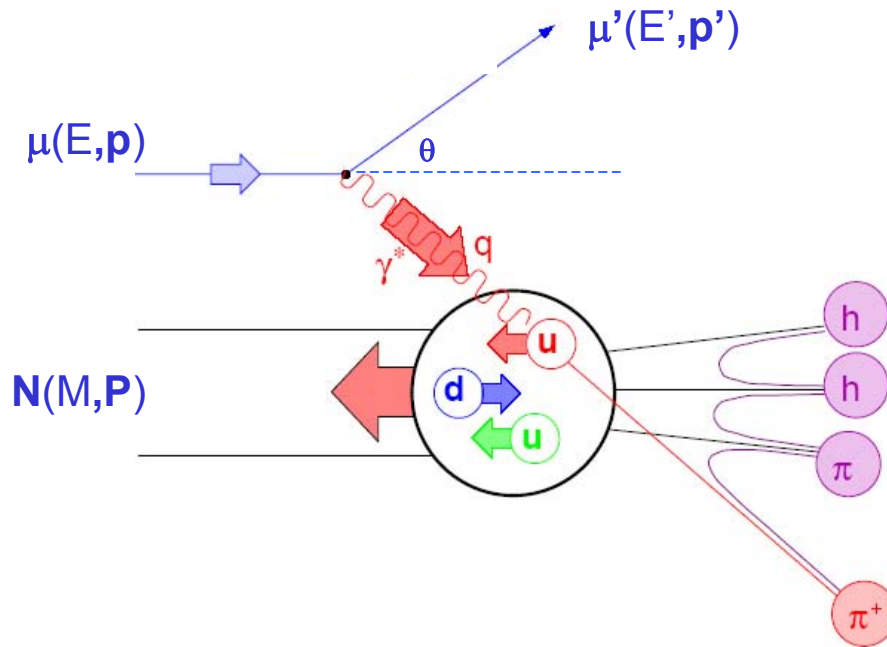
on behalf of the COMPASS Collaboration



- Polarised deep inelastic scattering
- The g_1 structure function
- Longitudinal spin structure functions
- The strange quark polarisation

International Workshop on Hadron Structure and Spectroscopy

Polarised Deep Inelastic Scattering



$$Q^2 = -q^2 = (\mathbf{k} - \mathbf{k}')^2$$

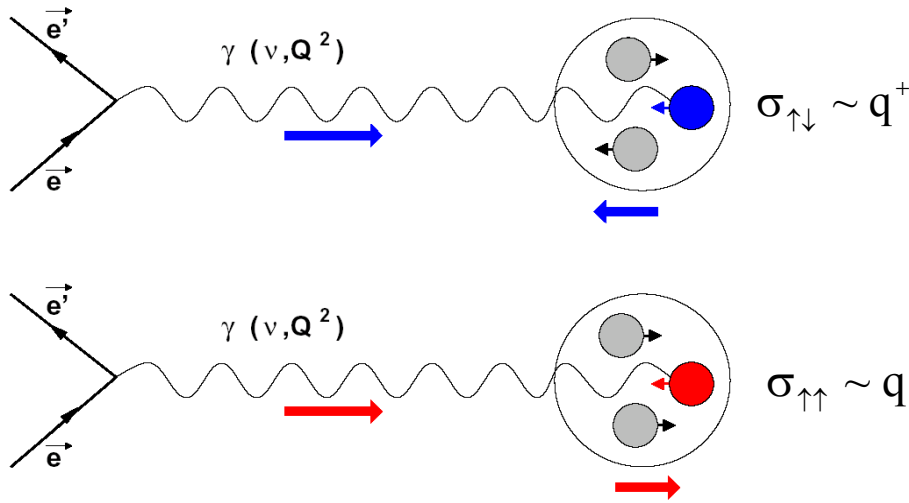
$$\nu = E - E'$$

$$x = Q^2/2M\nu$$

$$z = E_h/\nu$$

$$\frac{d^2\sigma}{d\Omega dE'} = \underbrace{c_1 F_1(x, Q^2) + c_2 F_2(x, Q^2)}_{\text{spin independent}} + \underbrace{c_3 g_1(x, Q^2) + c_4 g_2(x, Q^2)}_{\text{spin dependent}}$$

Photon-nucleon Asymmetry



$$\Delta q(x) = q(x)^+ - q(x)^-$$

$$q(x) = q(x)^+ + q(x)^-$$

+ quark $\uparrow\uparrow$ nucleon

- quark $\uparrow\downarrow$ nucleon

**Inclusive
asymmetry**

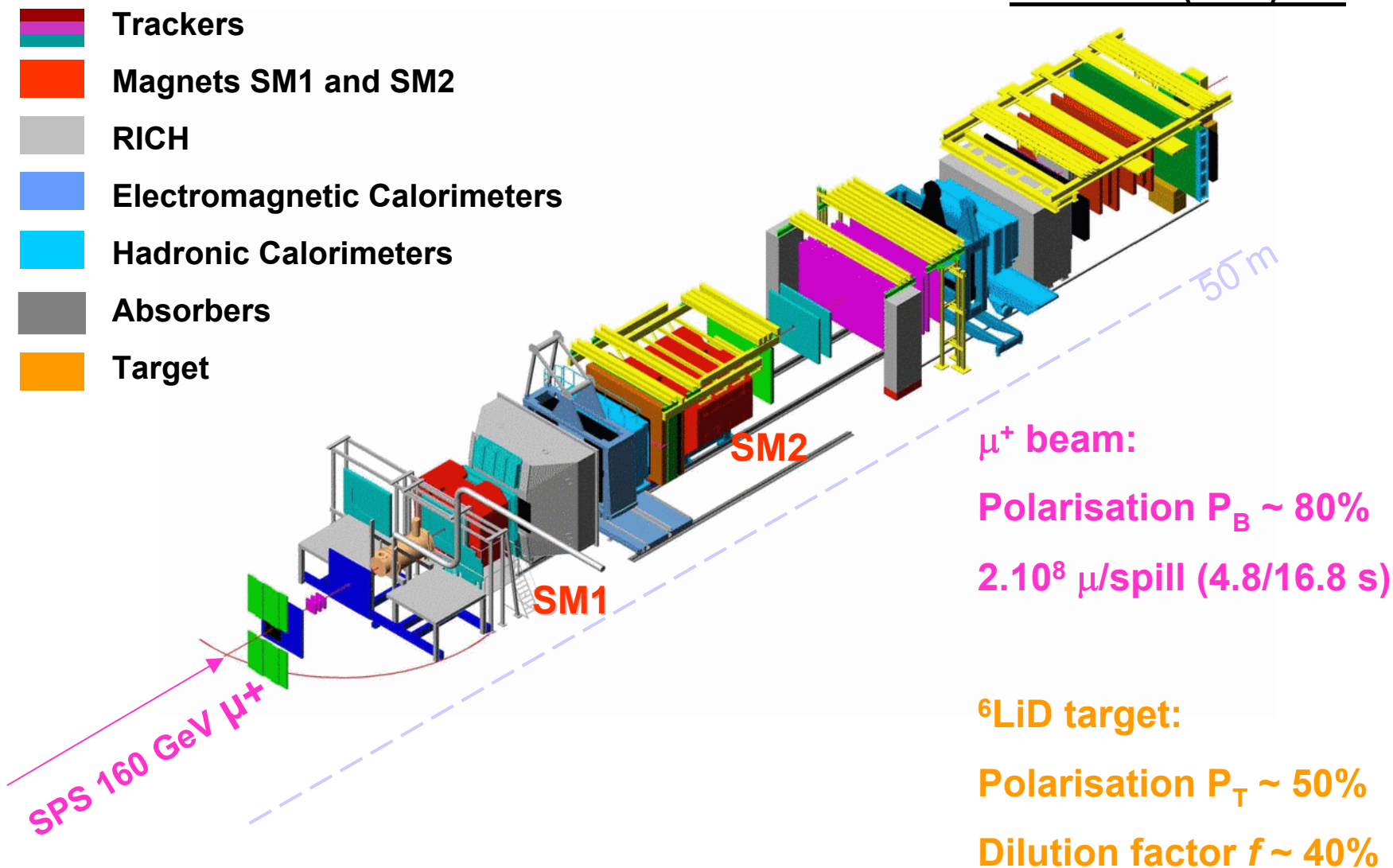
$$A_1(x, Q^2) = \frac{\sigma_{\uparrow\downarrow} - \sigma_{\uparrow\uparrow}}{\sigma_{\uparrow\downarrow} + \sigma_{\uparrow\uparrow}} \approx \frac{\sum_q e_q^2 \Delta q(x, Q^2)}{\sum_q e_q^2 q(x, Q^2)} = \frac{g_1(x, Q^2)}{F_1(x, Q^2)}$$

**Semi-inclusive
asymmetry**

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

The COMPASS Experiment

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Spectrometer Upgrade

Performed during SPS shutdown in 2005

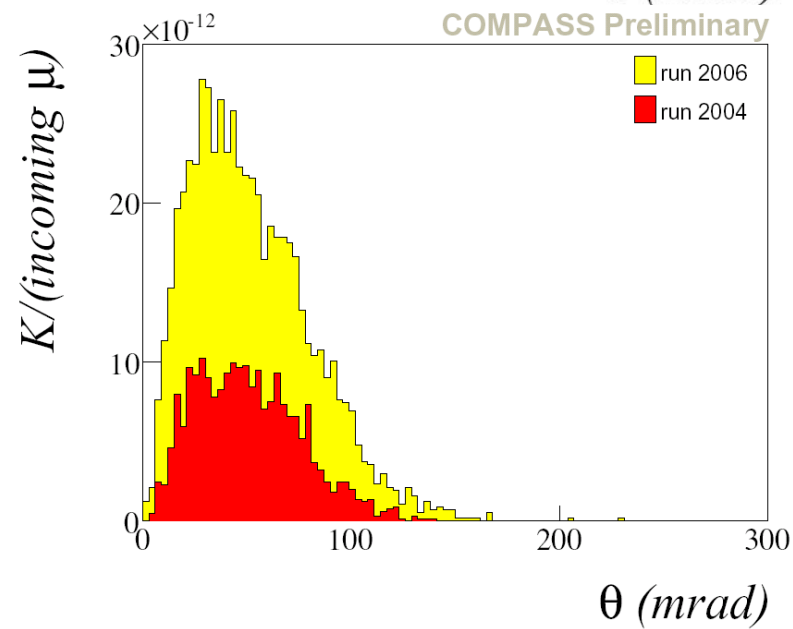
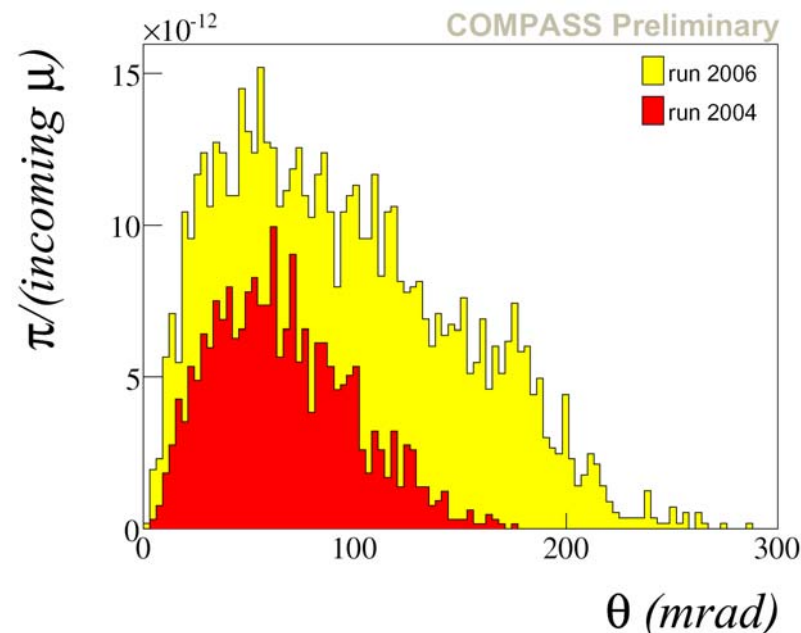
POLARISED TARGET

- Larger acceptance: 70 → 180 mrad
- 2 → 3 target cells for false asymmetries reduction

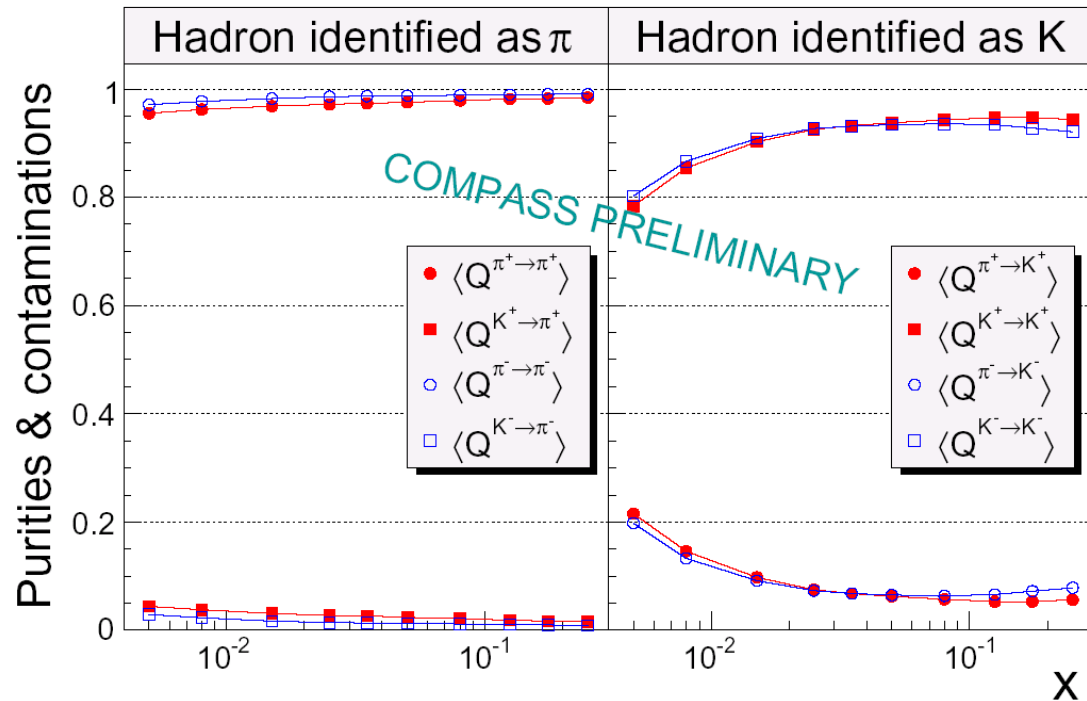
RICH DETECTOR

- Central part replaced by MAPMTs
→ Increase number of detected photons
- New readout system in the peripheral region

Improved resolution → π/K separation at 2.5σ up to 50 GeV/c

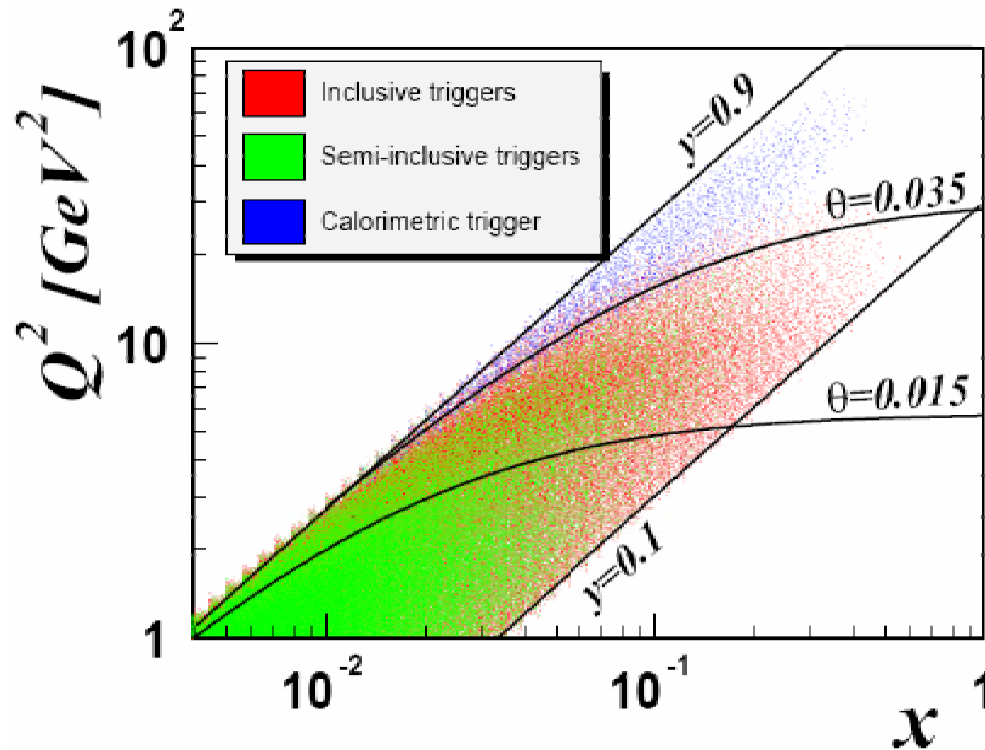


RICH Purities



- $Q^{t \rightarrow i}$ is the probability of a hadron, identified as type i , to be truly of type t

COMPASS Kinematic Domain

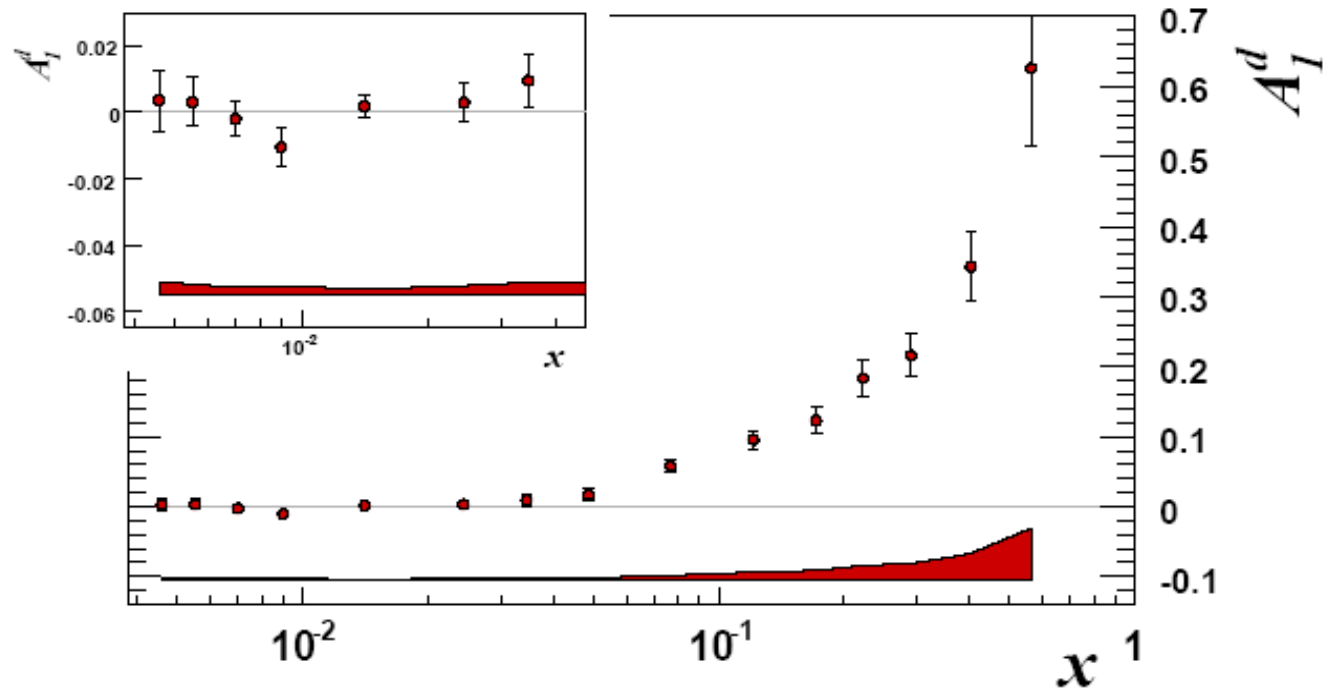


- (Invariant mass)² of the virtual photon: $Q^2 > 1 \text{ GeV}^2$
- Fraction of the energy carried by the virtual photon: $0.1 < y < 0.9$
- Bjorken scaling variable: $0.004 < x < 0.7$

Inclusive DIS Asymmetry

3 years of deuteron data taking, 2002 - 2004: 89×10^6 events

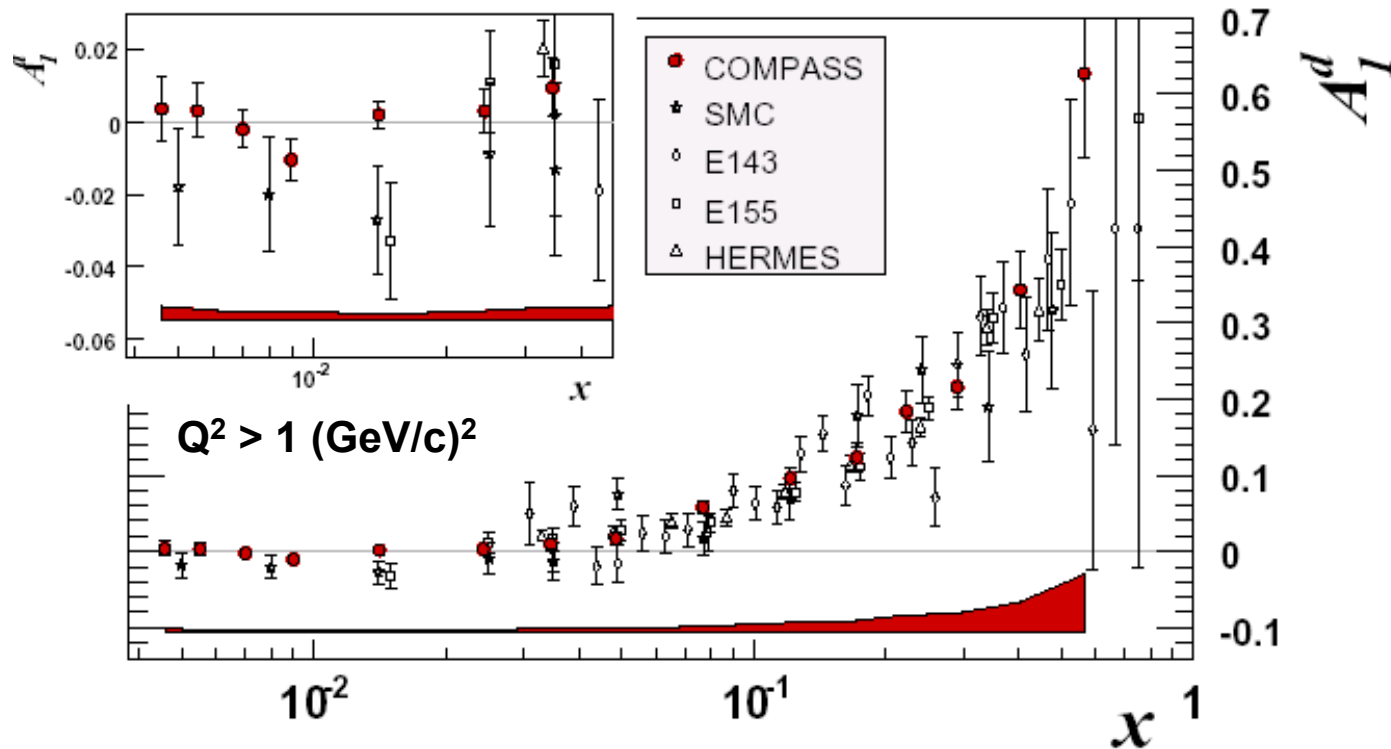
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- A_1 compatible with 0 for $x < 0.05$
- Large asymmetry at large x
- Systematic errors: Multiplicative $\rightarrow \delta \cong 0.10A$ (δP_B , δP_T , δf and δD)

Additive \rightarrow rad. corrections $\approx 10^{-4} - 10^{-3}$; $A_{false} < 0.4\delta A_{stat}$

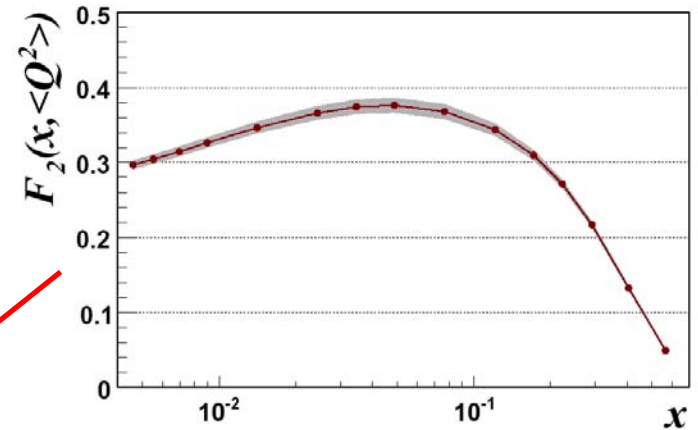
Inclusive DIS Asymmetry



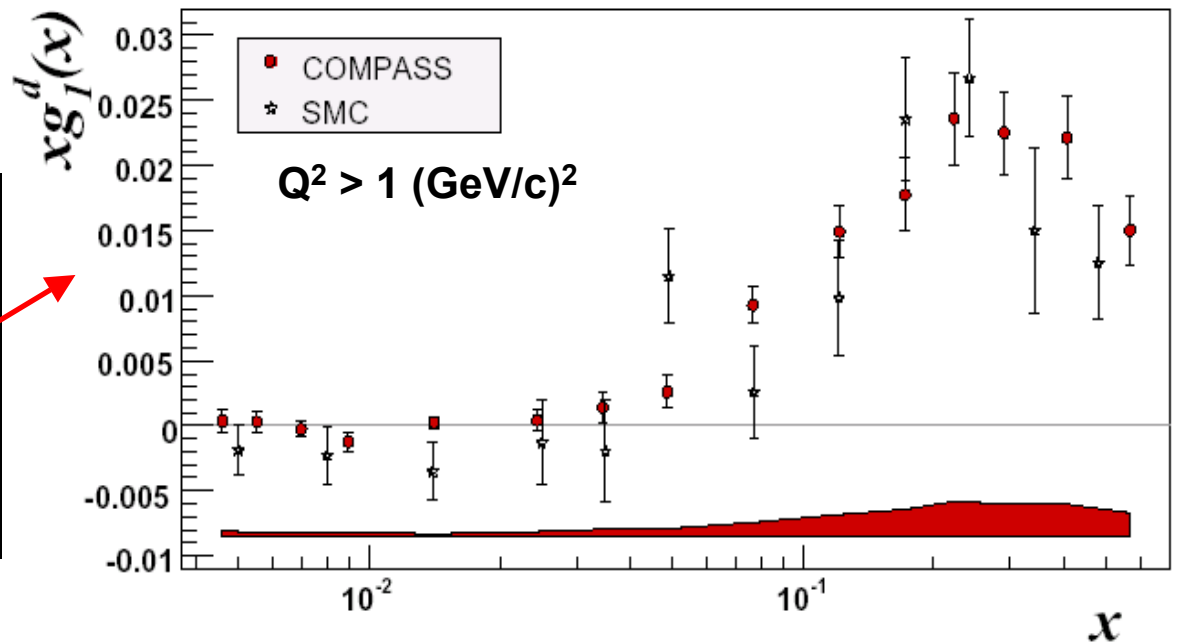
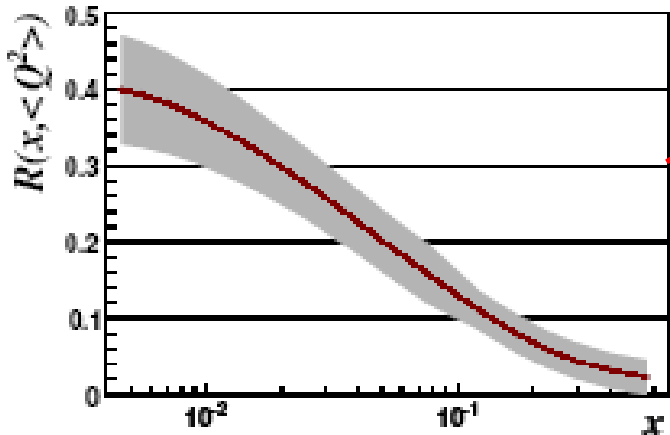
- Good agreement with previous experiments
- Improved significantly statistics at low x
- No tendency towards negative values at $x < 0.03$

The $g_1^d(x)$ Structure Function

$$g_1(x) = A_1(x) \frac{F_2(x)}{2x(1+R)}$$

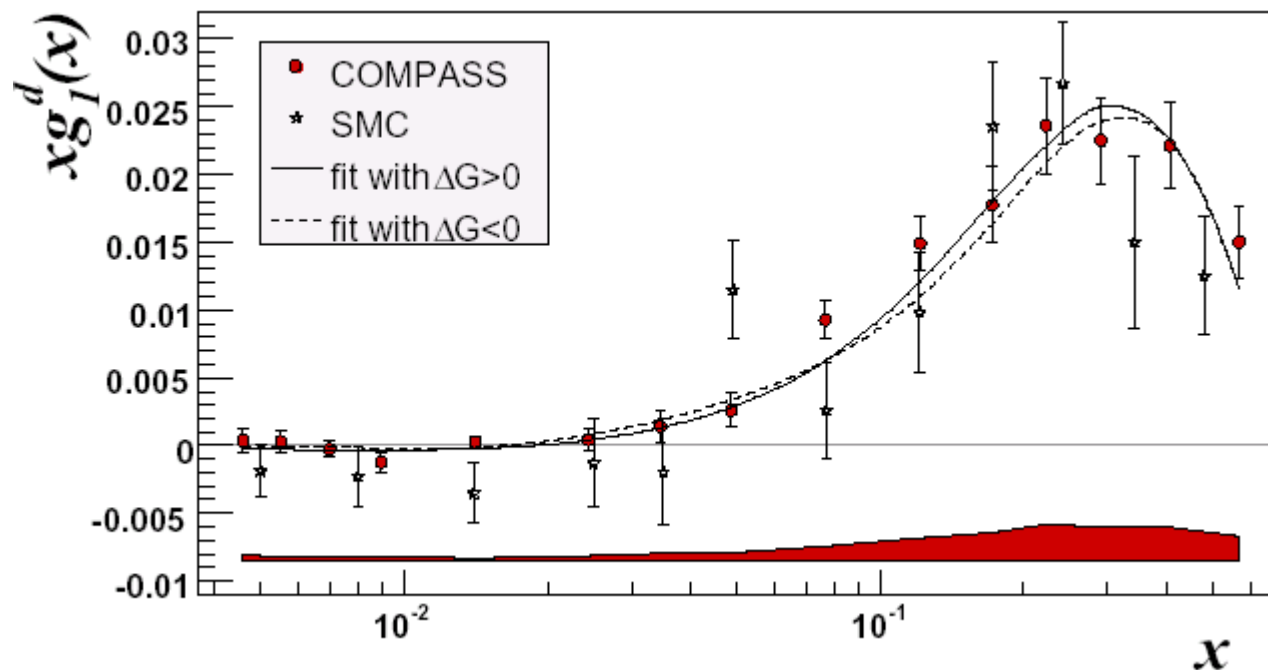


$$R(x, Q^2) = \sigma_L / \sigma_T$$



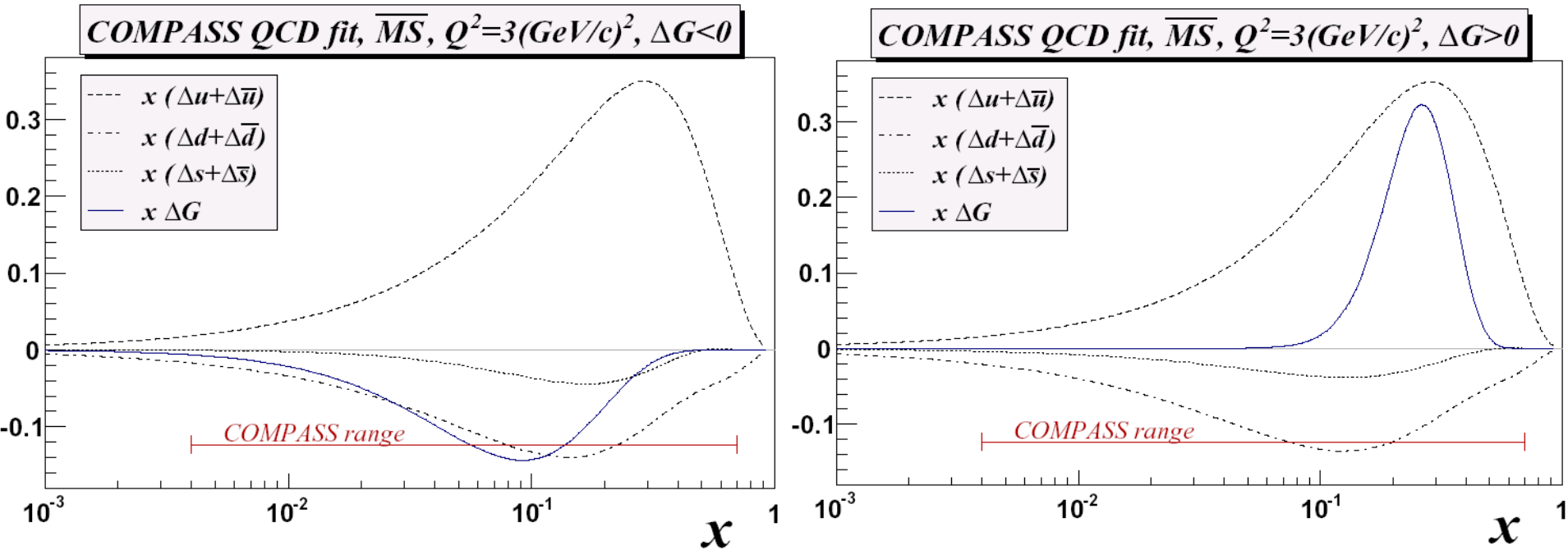
QCD Fits

- Fits to world data → 230 world data points, **43 from COMPASS**
- NLO analysis ($\overline{\text{MS}}$ scheme)



Data well described by two solutions: $\Delta G > 0$ and $\Delta G < 0$

Polarised Parton Distributions



✓ Very small sensitivity of $x(\Delta q + \Delta \bar{q})$ to $x\Delta G$

First Moment of g_1

(COMPASS data only)

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$$\Gamma_1^N(Q_0^2 = 3(\text{GeV}/c)^2) = \int_0^1 g_1^N(x) dx = 0.0502 \pm 0.0028(\text{stat}) \pm 0.0020(\text{evol}) \pm 0.0051(\text{syst})$$

• in literature (S.A. Larin *et al.*, PLB404 (1997) 153):

$$\Gamma_1^N(Q^2) = \frac{1}{9} \left(1 - \frac{\alpha_s(Q^2)}{\pi} + \mathcal{O}(\alpha_s^2) \right) \left(a_0(Q^2) + \frac{1}{4} a_8 \right) \quad \begin{array}{l} \text{(from Y. Goto } et al., \text{ PRD62 (2000) 034017:} \\ a_8 = 0.585 \pm 0.025) \end{array}$$

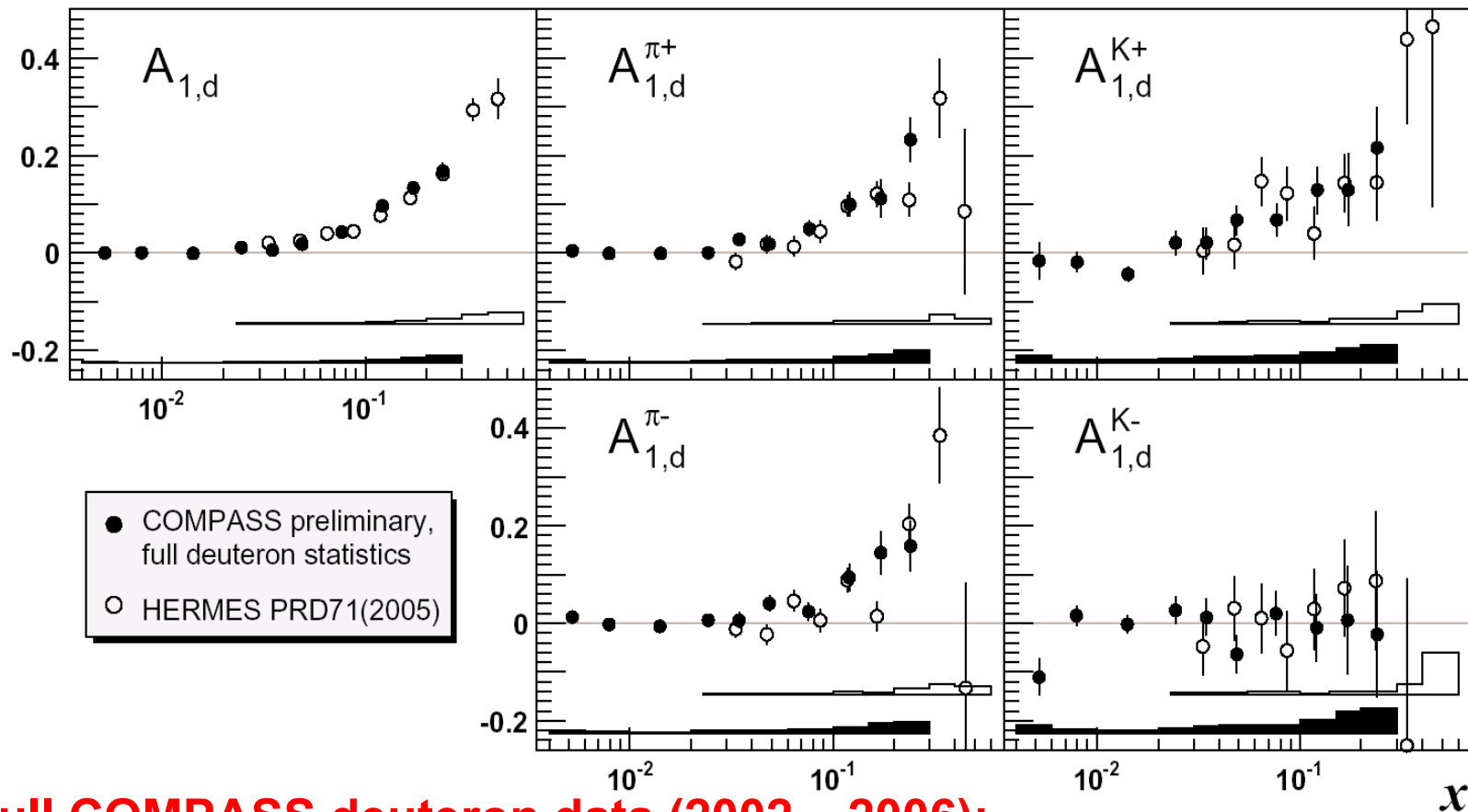
$$a_0(Q_0^2 = 3(\text{GeV}/c)^2) = 0.35 \pm 0.03(\text{stat}) \pm 0.05(\text{syst})$$

extrapolating to $Q^2 \rightarrow \infty$

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

$$(\Delta s + \Delta \bar{s}) = \frac{1}{3} (\hat{a}_0 - a_8) = -0.08 \pm 0.01(\text{stat}) \pm 0.02(\text{syst})$$

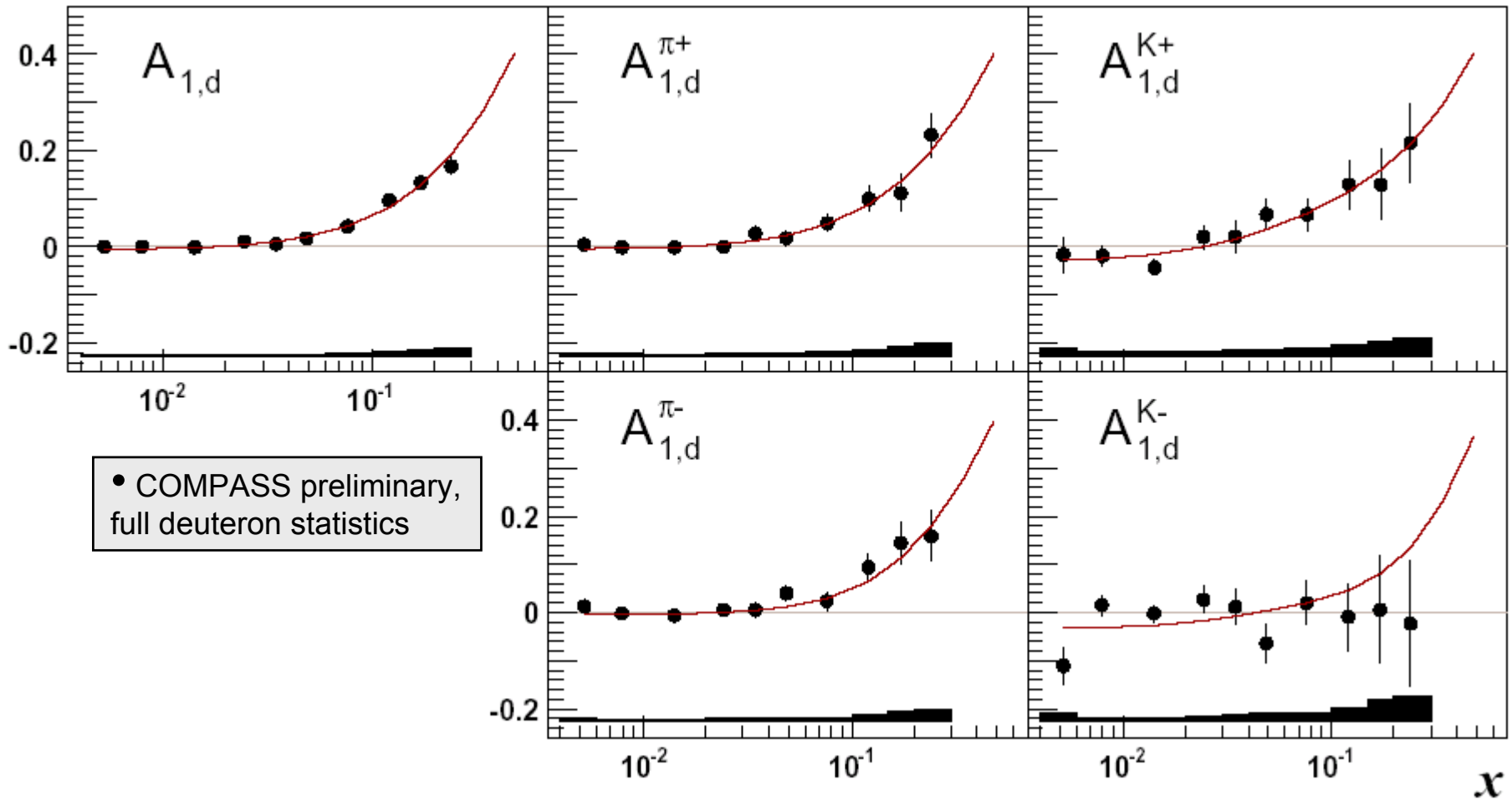
Semi-inclusive asymmetries



Full COMPASS deuteron data (2002 – 2006):

- **Phase space:** $Q^2 > 1(\text{GeV}/c)^2$, $0.004 < x < 0.3$, $10 < p < 50 \text{ GeV}/c$, $0.2 < z < 0.85$
- **Statistics:** $\pi^+ = 23 \times 10^6$, $\pi^- = 21 \times 10^6$, $K^+ = 4.8 \times 10^6$, $K^- = 3.3 \times 10^6$
- **Systematics errors:** $\delta \cong 0.08A$ (δP_B , δP_T , δf and δD); $\sigma_{\text{false asym}} < 0.4 \sigma_{\text{stat}}$

SIDIS Predictions



Curves are NLO predictions from DSSV Group (D. De Florian, R. Sassot, M. Stratmann and W. Vogelsang)

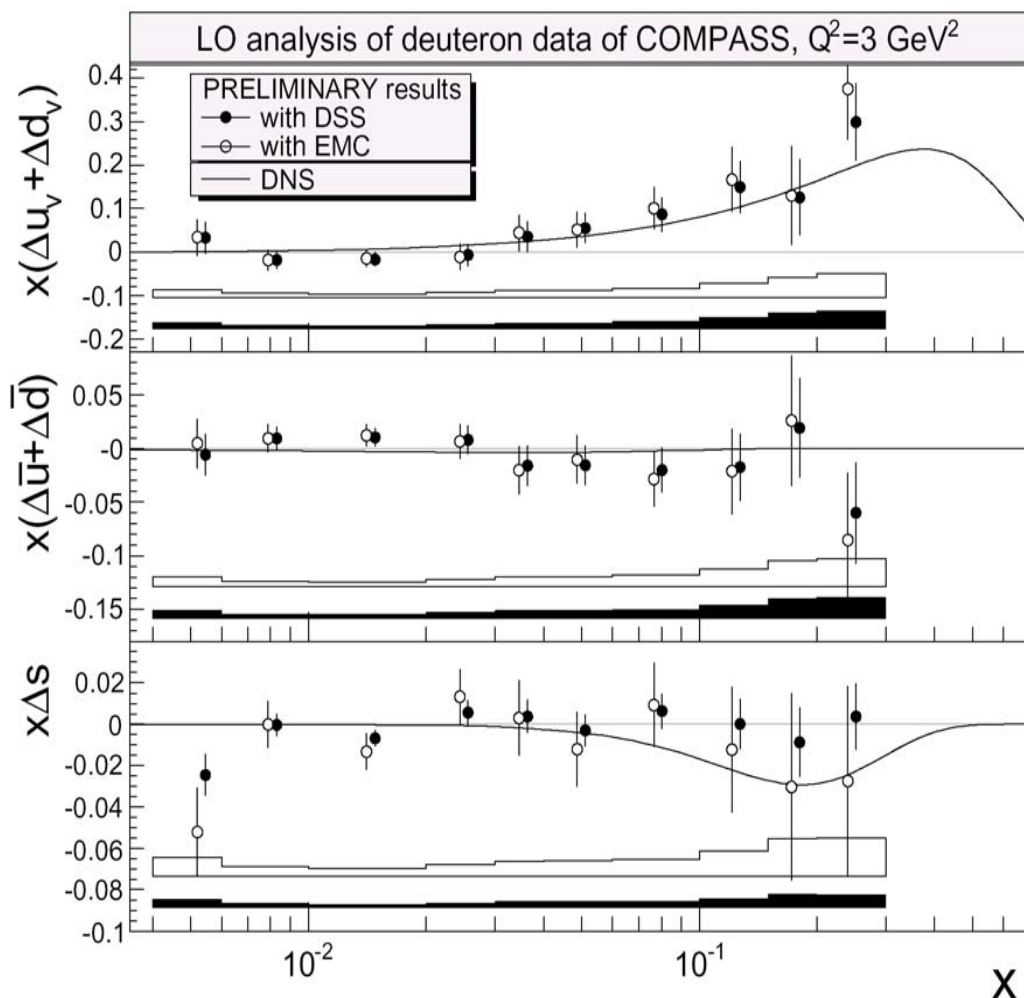
Polarised PDFs

LO evaluation of $\Delta u_v + \Delta d_v$, $\Delta \bar{u} + \Delta \bar{d}$ and Δs :

- Asymmetries assumed to be independent on $Q^2 \Rightarrow A_1^h(x, z) = \frac{\sum_q e_q^2 \Delta q(x) D_q^h(z)}{\sum_q e_q^2 q(x) D_q^h(z)}$
- $\Delta s \equiv \Delta \bar{s}$ assumed
- Unpolarised PDFs: **MRST04**
- Fragmentation functions:
 - ✓ **DSS** (global analysis of e^-e^+ , SIDIS and p+p collisions)
 - ✓ From **EMC** $D_u^{\pi^+, \pi^-}$ and $D_u^{K^+, K^-}$ measurements. (For comparison only.
 $D_{\bar{s}}^{K^+} = D_u^{\pi^+}$ assumed, in addition to charge conjugation and isospin symmetry. All unfavored FFs assumed to be equal.)

Least square fit in each x bin

Polarised PDFs (cont.)



$\Delta u_v + \Delta d_v$:
small sensitivity to
different FFs; good
agreement with DNS curve

$\Delta \bar{u} + \Delta \bar{d}$:
compatible with 0; little
effect from different FFs

Δs :
statistical errors 2–3 times
larger with EMC FFs

LO DNS analysis, based on KKP param. of FFs, includes all DIS g_1 prior to **COMPASS 2004** data and all SIDIS data from **SMC** and **HERMES**

First Moments

Full deuteron data: 2002 – 2006

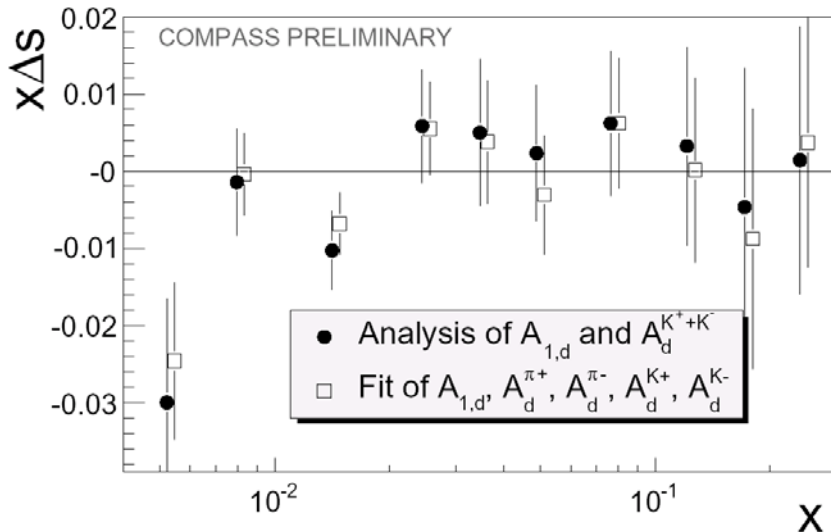
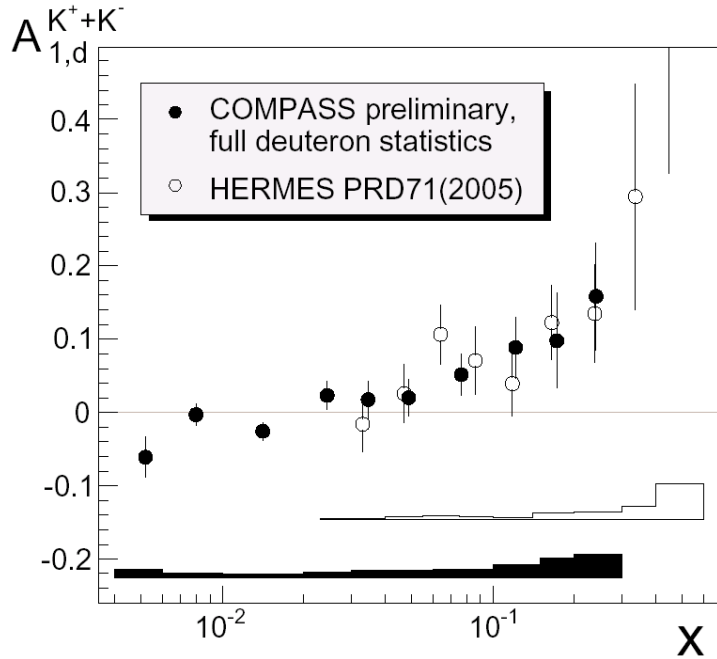
	FF's from DSS
$\Delta u_v + \Delta d_v$	$0.28 \pm 0.06 \pm 0.03$
$\Delta \bar{u} + \Delta \bar{d}$	$-0.03 \pm 0.03 \pm 0.01$
$\Delta s \equiv \Delta \bar{s}$	$-0.01 \pm 0.01 \pm 0.01$

- Truncated to measured range ($0.004 < x < 0.3$), at $Q^2 = 3 \text{ (GeV/c)}^2$
- $\int_{0.3}^1 \Delta s(x) dx \leq 0.002$ (positivity condition)

From COMPASS 2002-2004 results:

- $\Delta u_v + \Delta d_v = 0.26 \pm 0.07 \pm 0.04$, from $A_1^{h^+h^-}$ approach (at $Q^2 = 10 \text{ (GeV/c)}^2$)
- $\Delta \bar{u} + \Delta \bar{d} = 0.0 \pm 0.04 \pm 0.03$ ($0 < x < 1$) Phys. Lett. B 660 (2008) 458
- $\Delta s = -0.045 \pm 0.005 \pm 0.010$, from Γ_1 ($0 < x < 1$) – LO evaluation Phys. Lett. B 647 (2007) 8

Δs from charged kaon asymmetry



$$\frac{\Delta s}{s} = A_1^d + \left(A_1^{K^+K^-} - A_1^d \right) \frac{Q/s + \alpha}{\alpha - 0.8}$$

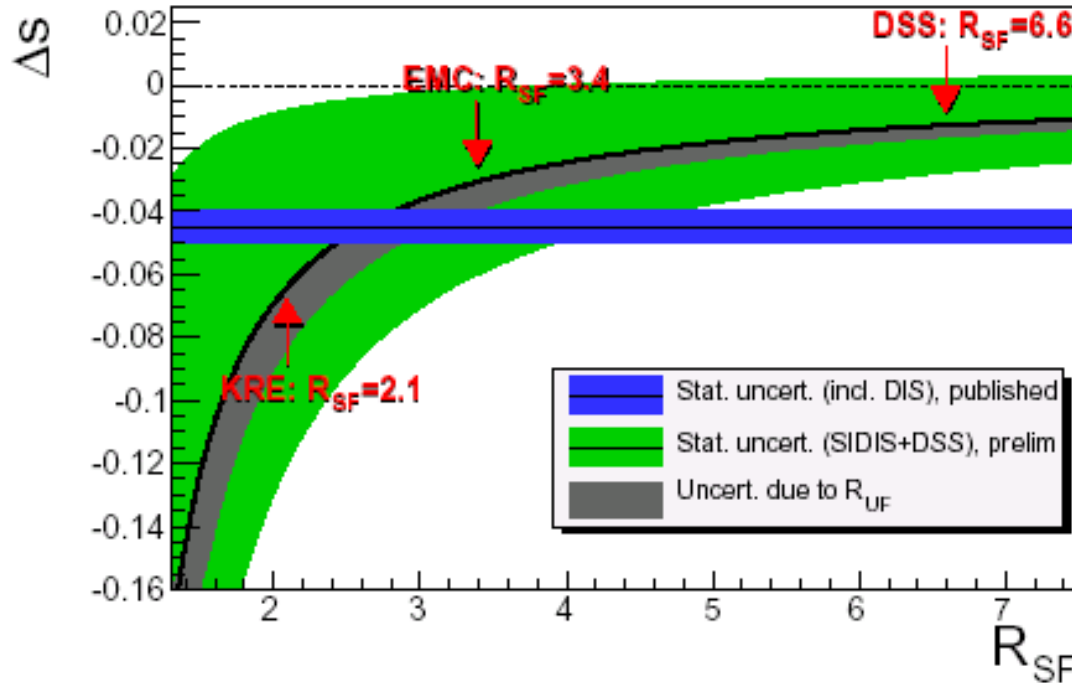
$$\alpha = \frac{2R_{UF} + 2R_{SF}}{3R_{UF} + 2} \quad Q = u + \bar{u} + d + \bar{d}$$

$$R_{UF} = \frac{\int D_d^{K^+}(z) dz}{\int D_u^{K^+}(z) dz} \quad R_{SF} = \frac{\int D_s^{K^+}(z) dz}{\int D_u^{K^+}(z) dz}$$

if $A_1^d = A^{K^+K^-} \Rightarrow \Delta s \geq 0$, insensitive to FFs

if $A^{K^+K^-} < 0$ (at low x) $\Rightarrow \Delta s < 0$

Δs as a function of R_{SF}



$$R_{SF} = \frac{\int D_s^{K^+}(z) dz}{\int D_u^{K^+}(z) dz}$$

$$R_{UF} = \frac{\int D_d^{K^+}(z) dz}{\int D_u^{K^+}(z) dz}$$

- R_{UF} fixed at 0.14 from the DSS fragmentation functions
- Large statistical uncertainty due to R_{SF} ; slight dependence on R_{UF}
- If $R_{SF} \geq 5$: $\Delta S(\text{SIDIS}) > \Delta S(\text{DIS}) \Rightarrow \Delta S(x) < 0$ for $x < 0.004$ (unmeasured), but 2σ difference only
- If $R_{SF} \leq 4$: $\mathbf{A}^{K^++K^-}$ becomes insensitive to Δs (small $\mathbf{D}_s^{K^+}$)

Conclusions

From the first moment of g_1^d and semi-inclusive asymmetries, we extract the Δs contribution to the nucleon spin:

$$\Delta s \text{ (inclusive)} = -0.045 \pm 0.005 \pm 0.010$$

$$\Delta s \text{ (SIDIS)} = -0.01 \pm 0.01 \pm 0.01$$

Strange quark polarisation strongly dependent on R_{SF} . Comparison between first moments of Δs from DIS and SIDIS limited by statistics

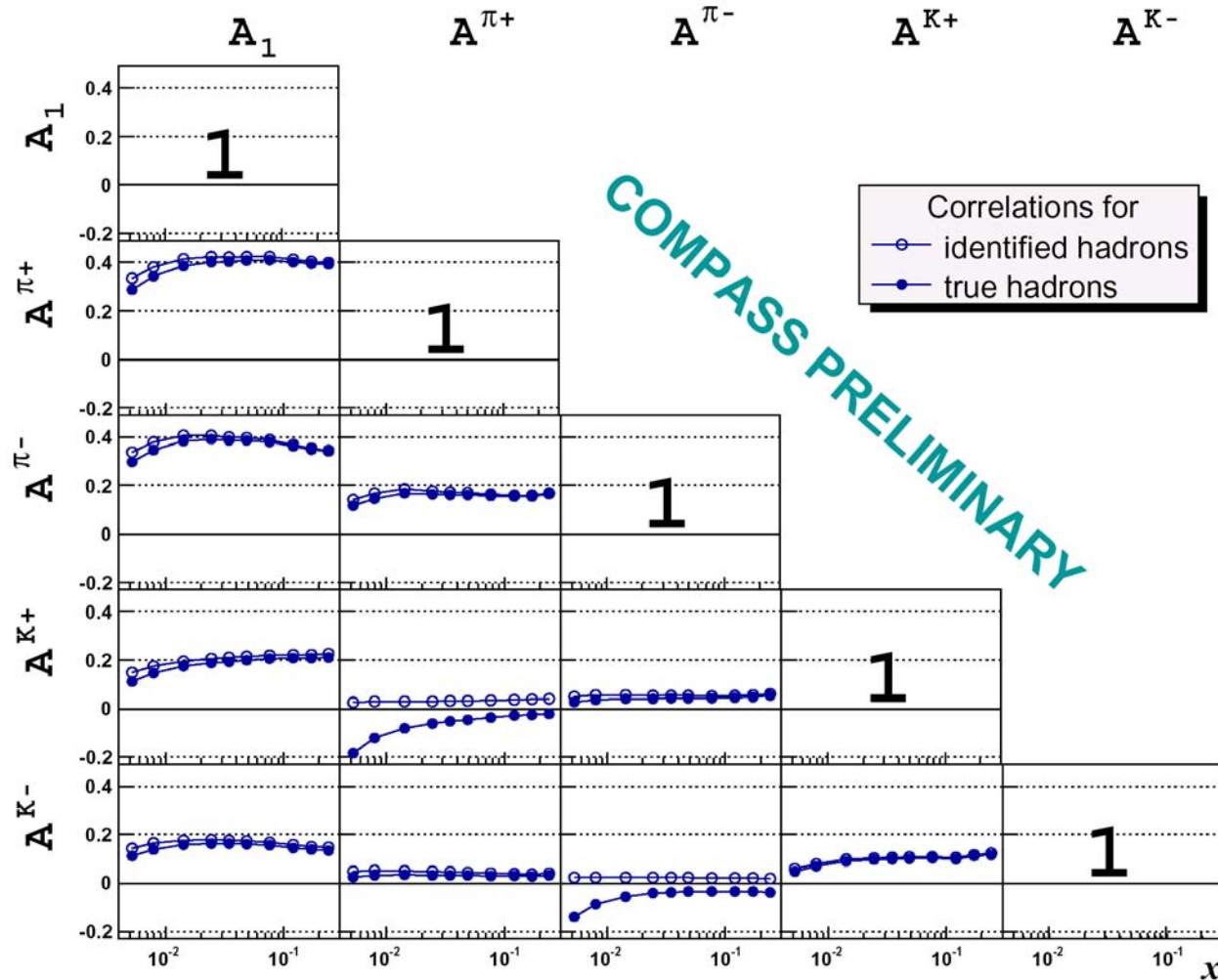
New evaluation of valence quark polarisations

Sea polarisation is consistent with 0 over the measured range

Analysis of 2007 COMPASS proton data coming soon

Spares

Correlations



Asymmetry correlation matrices, before and after unfolding

PDFs before and after unfolding

