COMPASS Results on the Strange Quark Polarisation

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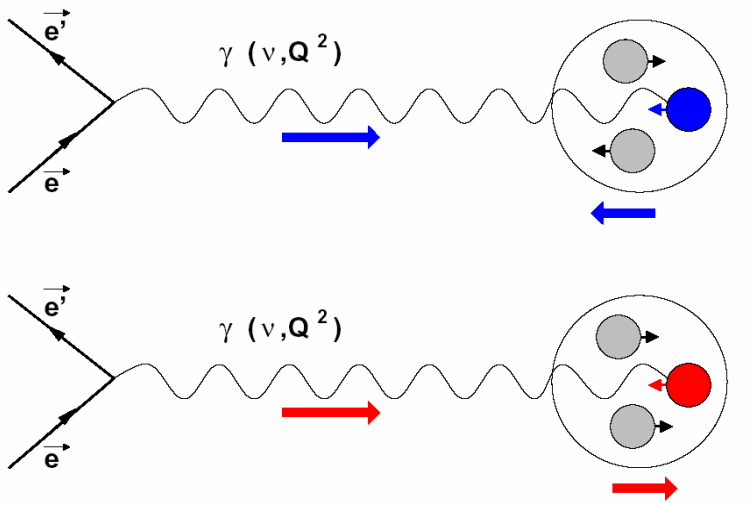
on behalf of the COMPASS Collaboration

- The g_1 structure function
- Longitudinal spin structure functions
- The strange quark polarisation

XVII International Workshop on Deep-Inelastic Scattering and Related Subjects

Polarised Deep Inelastic Scattering



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

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

\+ quark ↑↑ nucleon

– quark ↑↓ 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

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

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The COMPASS Experiment

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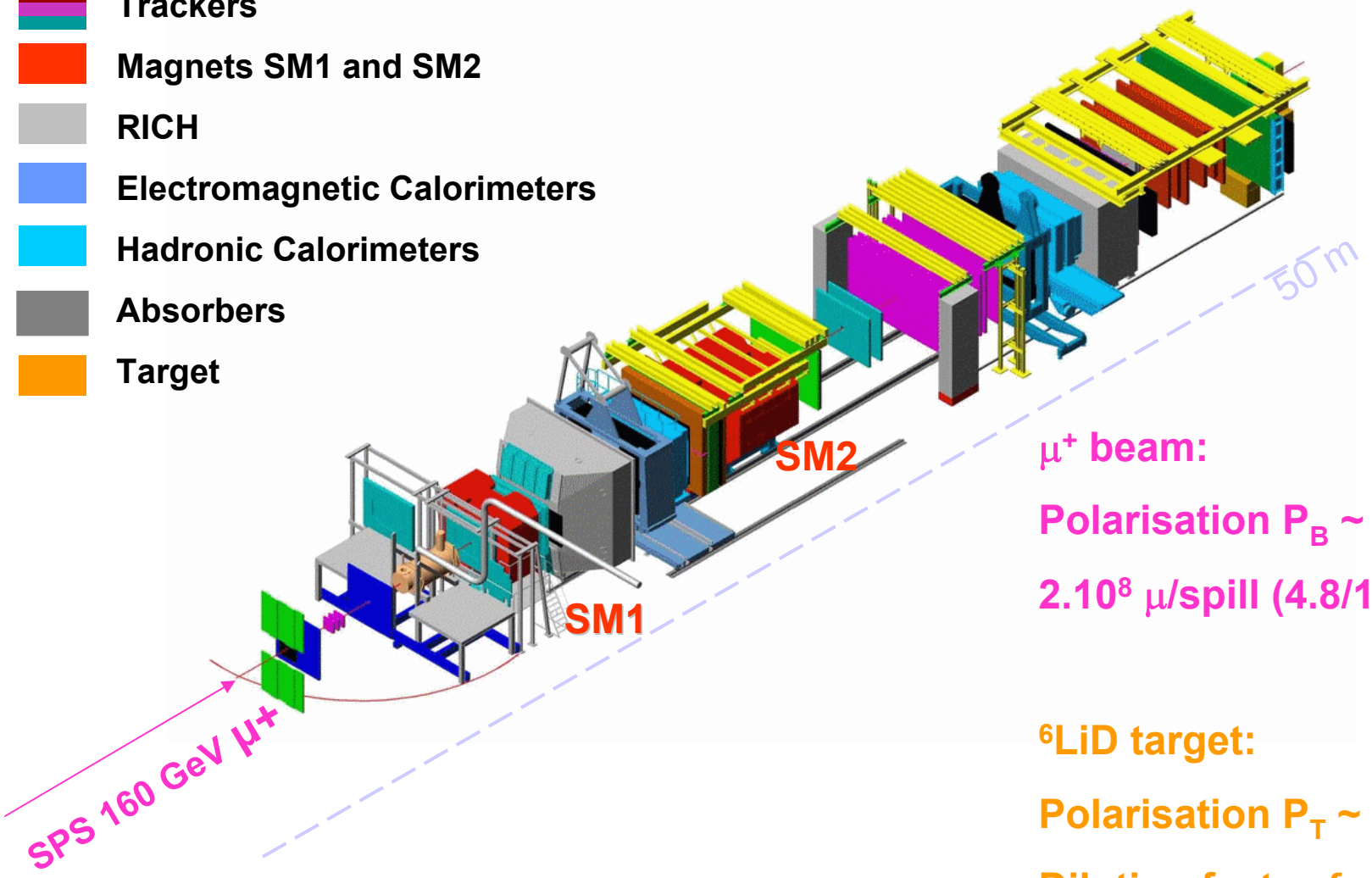
- Trackers
- Magnets SM1 and SM2
- RICH
- Electromagnetic Calorimeters
- Hadronic Calorimeters
- Absorbers
- Target



μ^+ beam:

Polarisation $P_B \sim 80\%$

2.10^8 μ/spill (4.8/16.8 s)

^{6}LiD target:

Polarisation $P_T \sim 50\%$

Dilution factor $f \sim 40\%$

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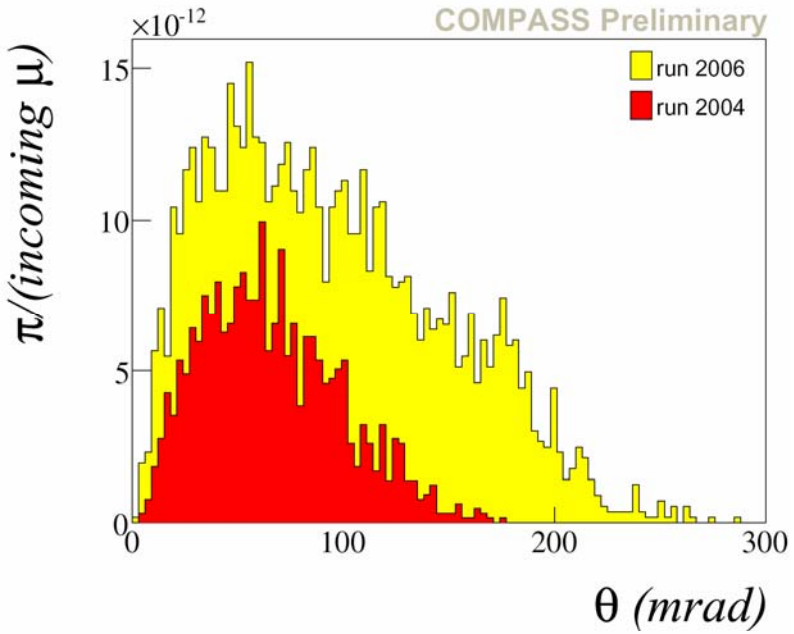
Spectrometer Upgrade

Performed during SPS shutdown in 2005

POLARISED TARGET

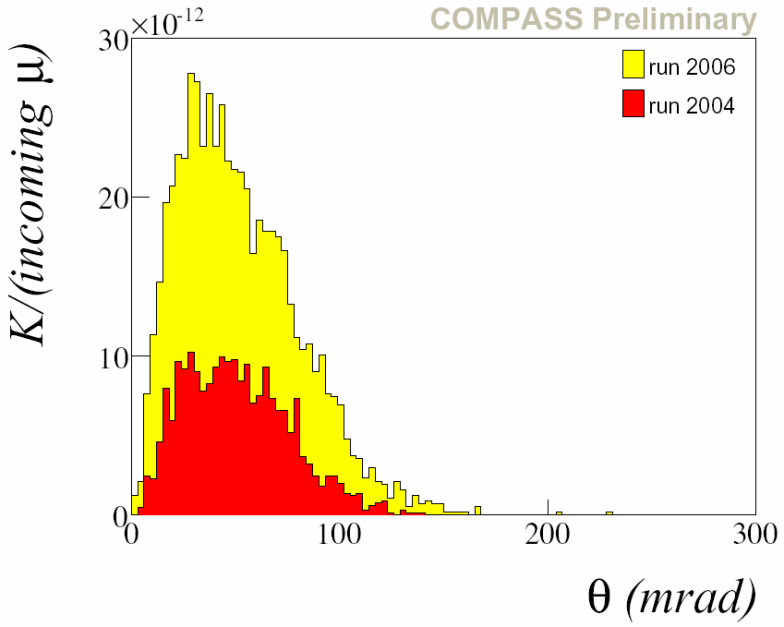
- Larger acceptance: 70 → 180 mrad
- 2 → 3 target cells for false asymmetries reduction



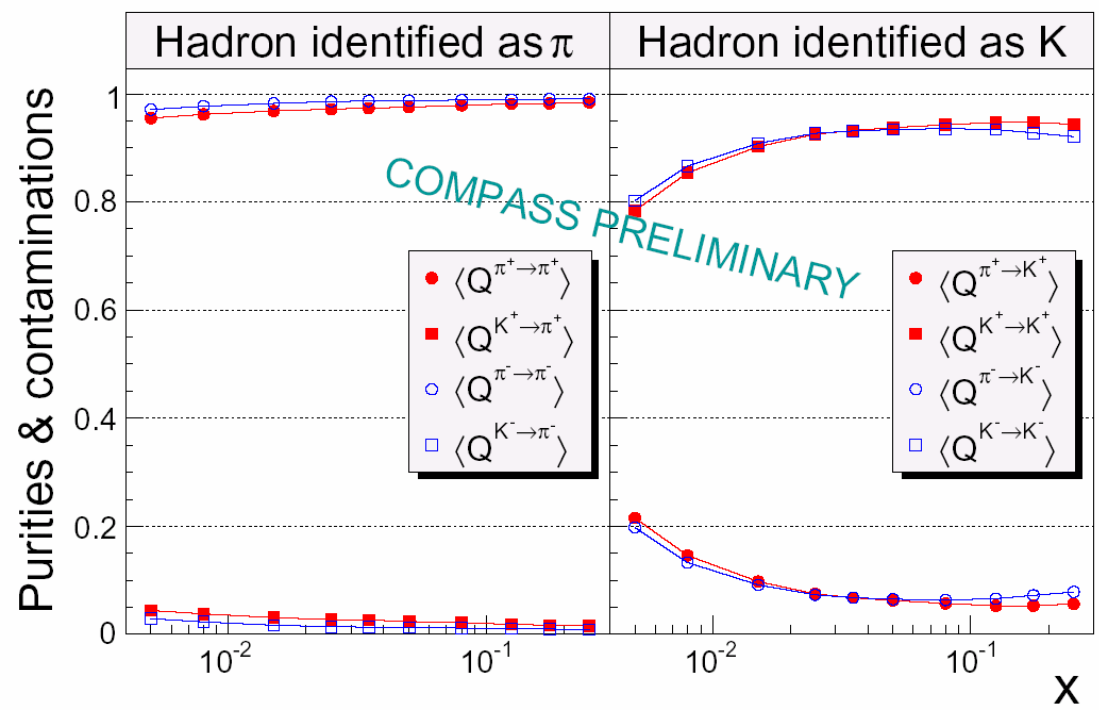
RICH DETECTOR

- 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



- $Q^{t \to i}$ is the probability of a hadron, identified as type *i,* to be truly of type *t*
- Unfolding method is applied in bins of momentum and polar angle

→ effect on asymmetries is small

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Inclusive DIS Asymmetry

3 years of deuteron data taking, 2002 - 2004: 89x10^6 events

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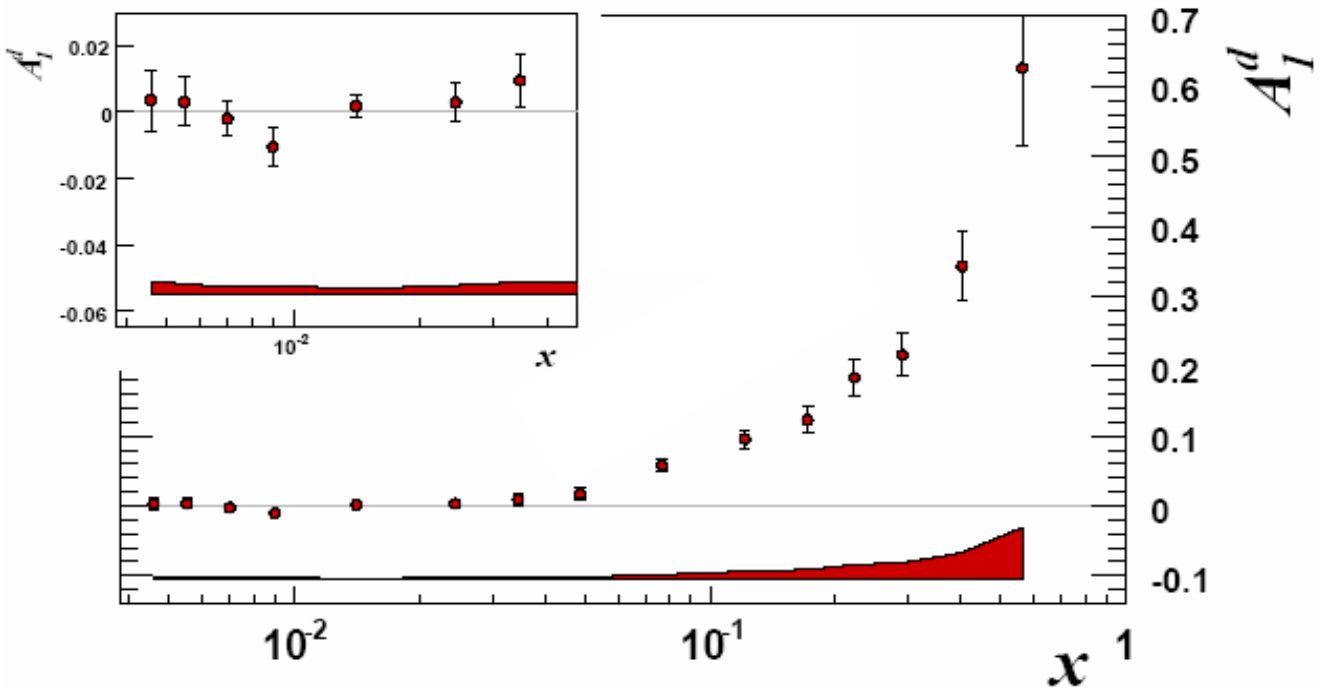

$Q^2 > 1$ (GeV/c)^2

$0.1 < y < 0.9$

$0.004 < x < 0.7$

- 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}; $A_{false} < 0.4\delta A_{stat}$

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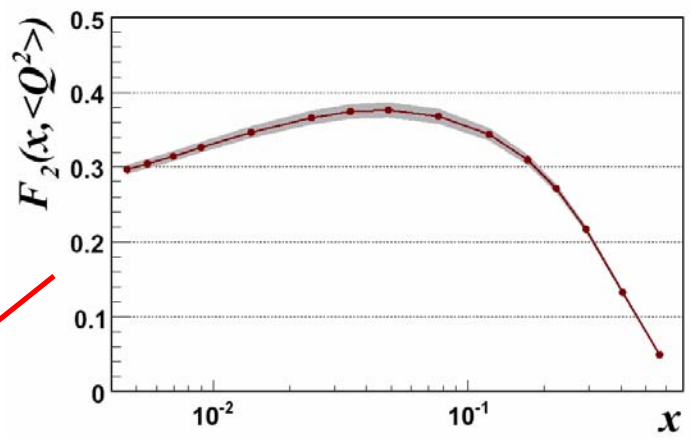
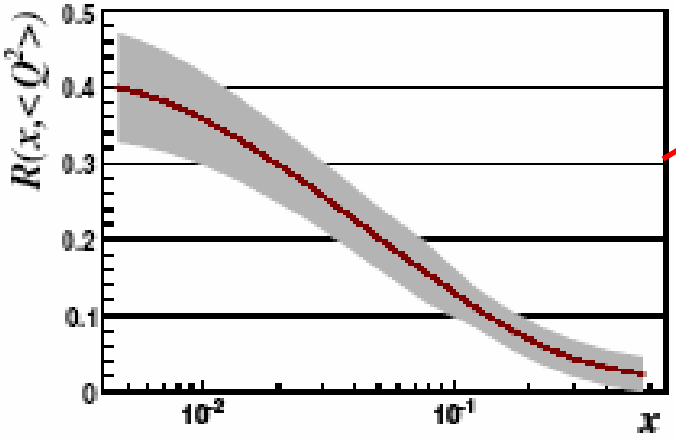
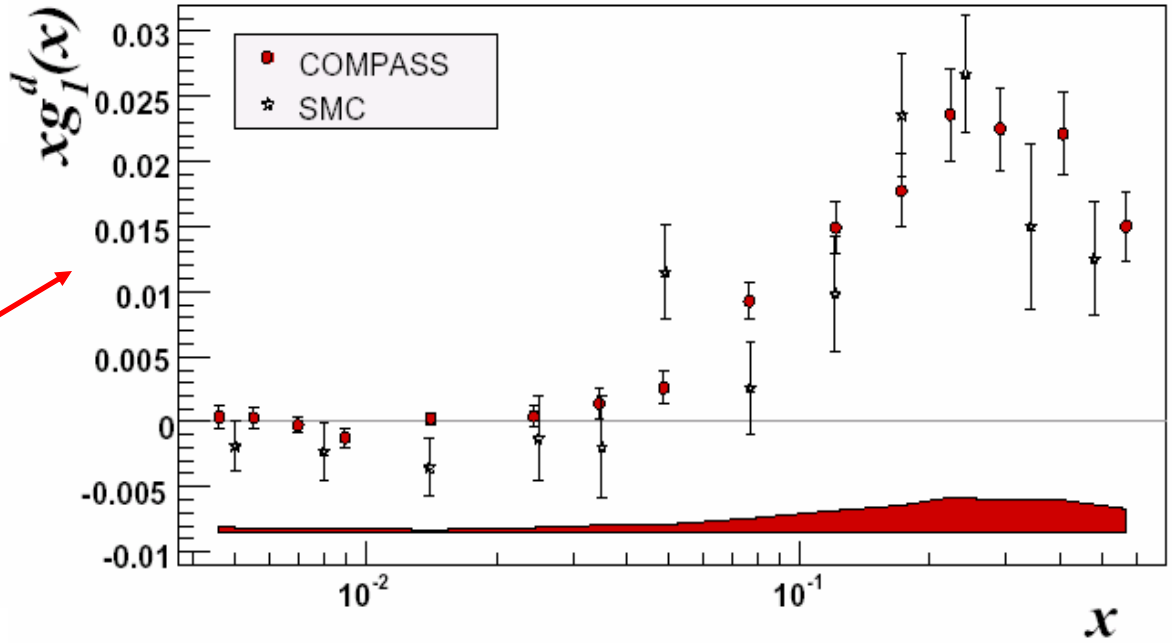
The $g_1^d(x)$ Structure Function

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



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





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First Moment of g_1

(COMPASS data only)

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

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

$$\Gamma_1^N(Q^2) = \frac{1}{9}\left(1 - \frac{\alpha_s(Q^2)}{\pi} + O(\alpha_s^2)\right)\left(a_0(Q^2) + \frac{1}{4}a_8\right)$$

(from Y. Goto *et al.*, PRD62 (2000) 034017: $a_8 = 0.585 \pm 0.025$)

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

extrapolating to $Q^2 \to \infty$

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

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

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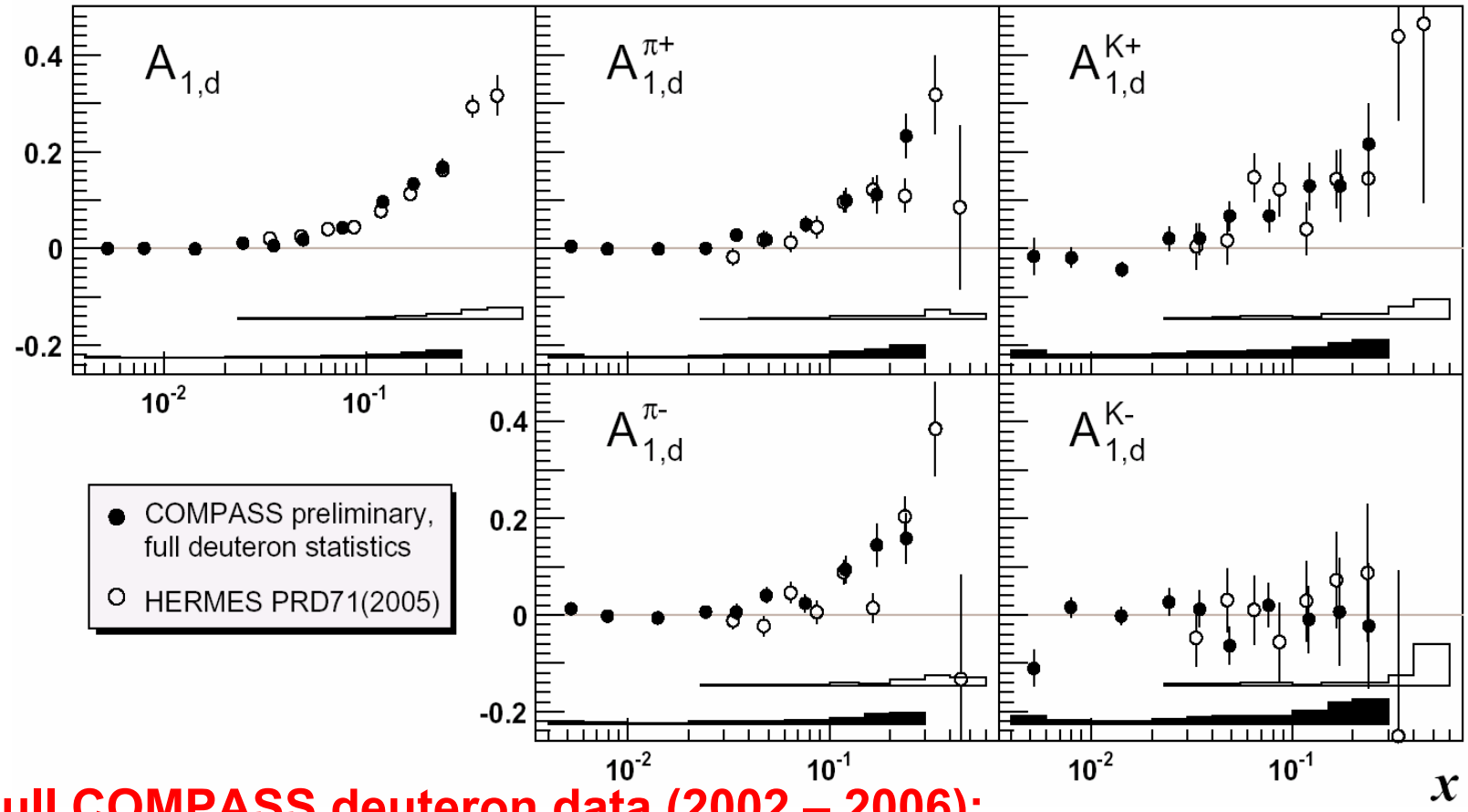
Semi-inclusive asymmetries



Full COMPASS deuteron data (2002 – 2006):

- **Phase space:** $Q^2 > 1(GeV/c)^2$, $0.004 < x < 0.3$, $10 < p < 50$ GeV/c, $0.2 < z < 0.85$
- **Statistics:** $\pi^+ = 23\times10^6$, $\pi^- = 21\times10^6$, $K^+ = 4.8\times10^6$, $K^- = 3.3\times10^6$
- **Systematics errors:** $\delta \cong 0.08A$ (δP_B, δP_T, δf and δD); $\sigma_{false\ asym} < 0.4\sigma_{stat}$

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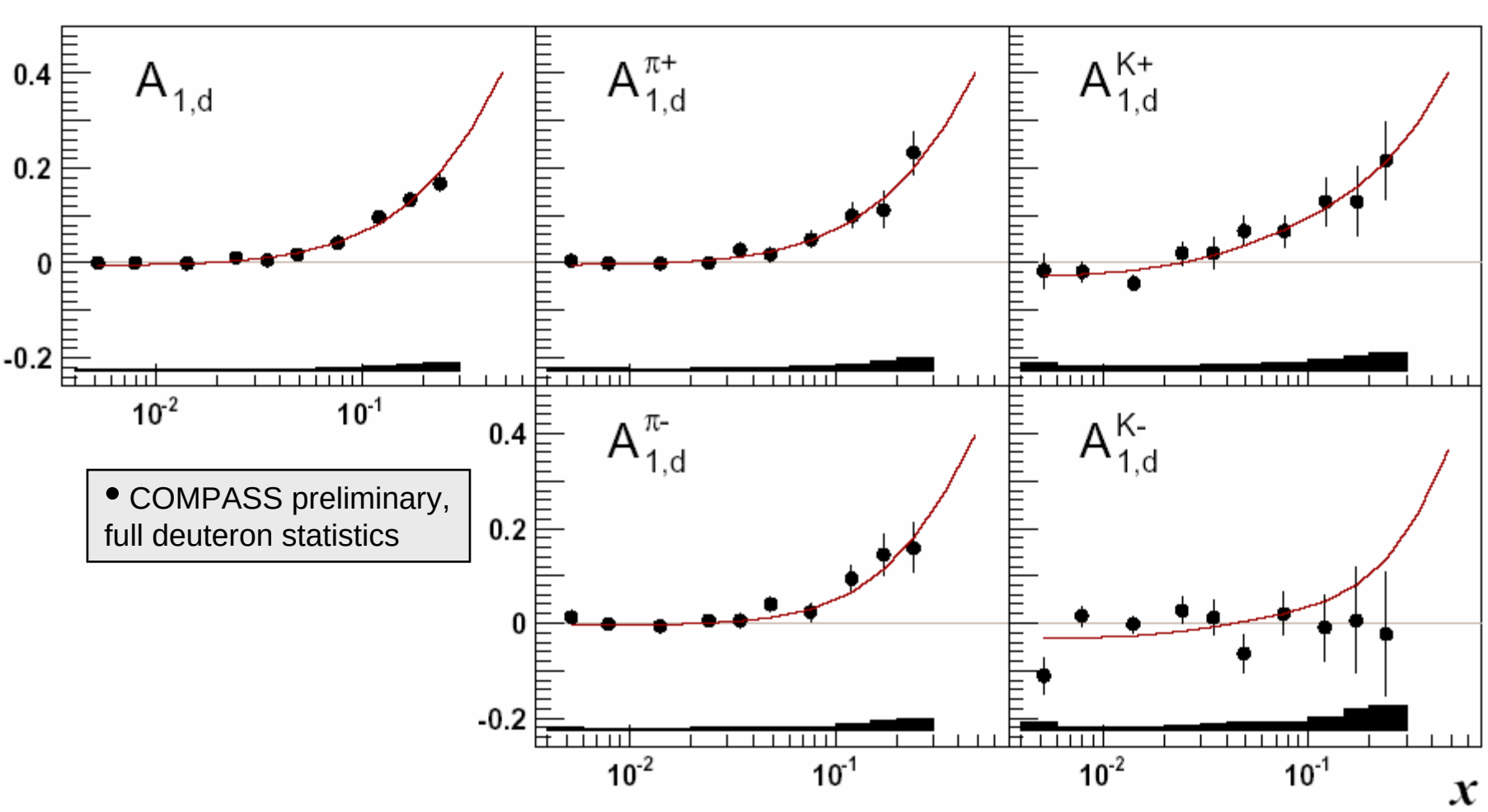
SIDIS Predictions



- COMPASS preliminary, full deuteron statistics

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

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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** $\Rightarrow A_1^h(x,z)=\dfrac{\sum_q e_q^2\,\Delta q(x)D_q^h(z)}{\sum_q e_q^2\,q(x)D_q^h(z)}$
- **$\Delta s \equiv \Delta\bar{s}$ 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

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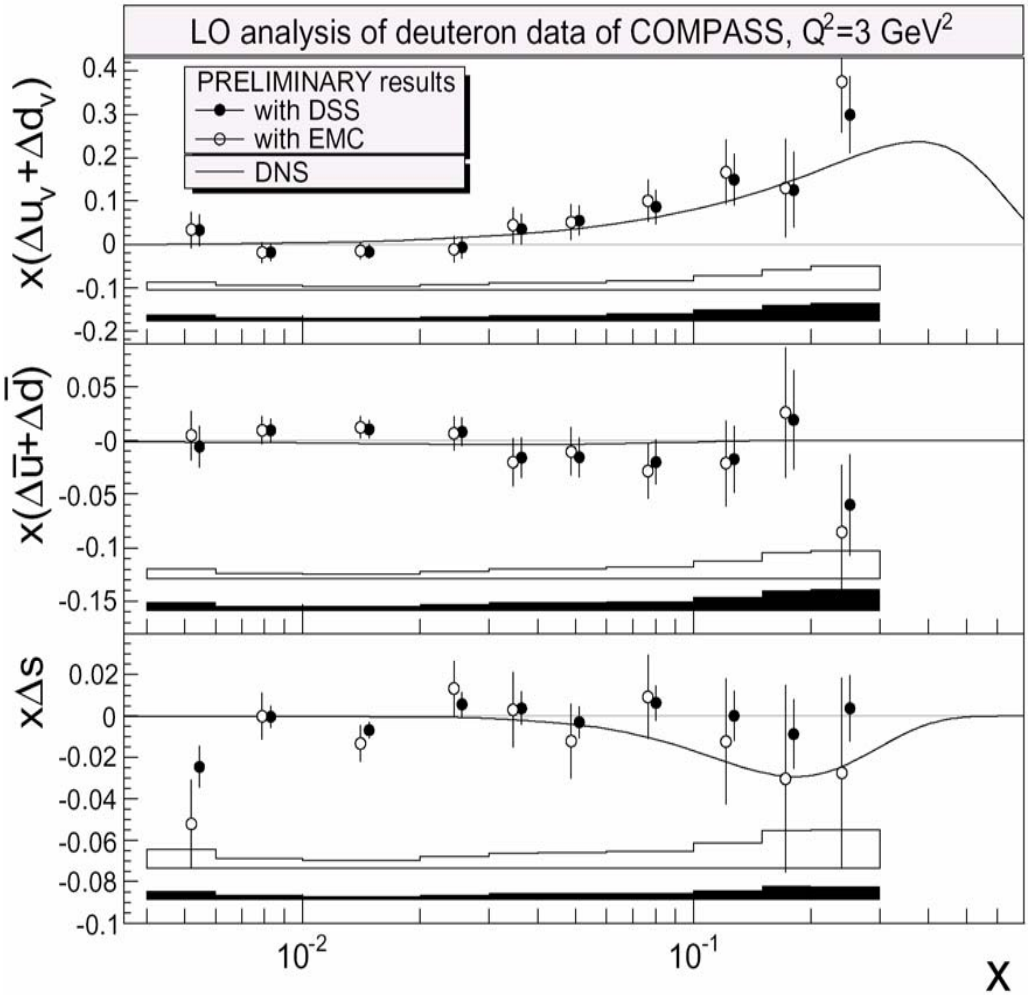
Polarised PDFs (cont.)



$\Delta u_v + \Delta d_v$:
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

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First Moments

Full deuteron data: 2002 – 2006

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

Preliminary

- **Truncated to measured range ($0.004 < x < 0.3$), at $Q^2 = 3$ (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 $Q^2 = 10$ (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

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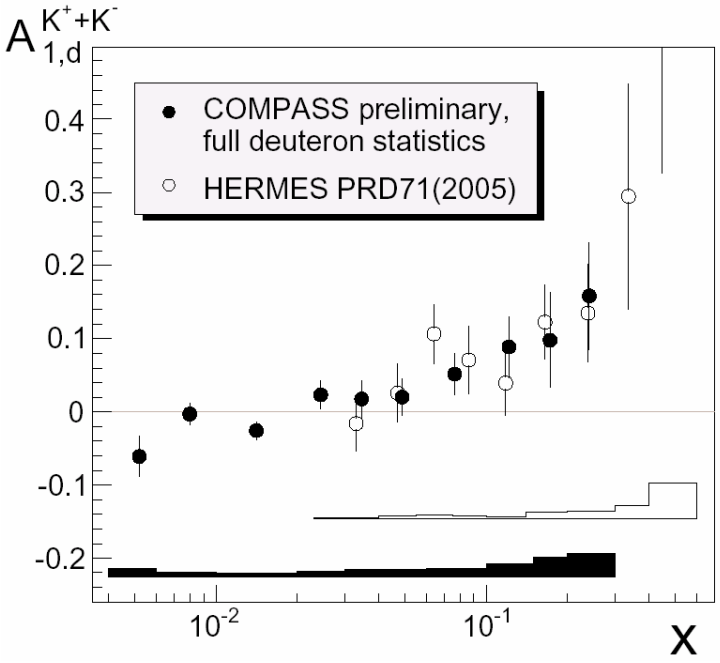
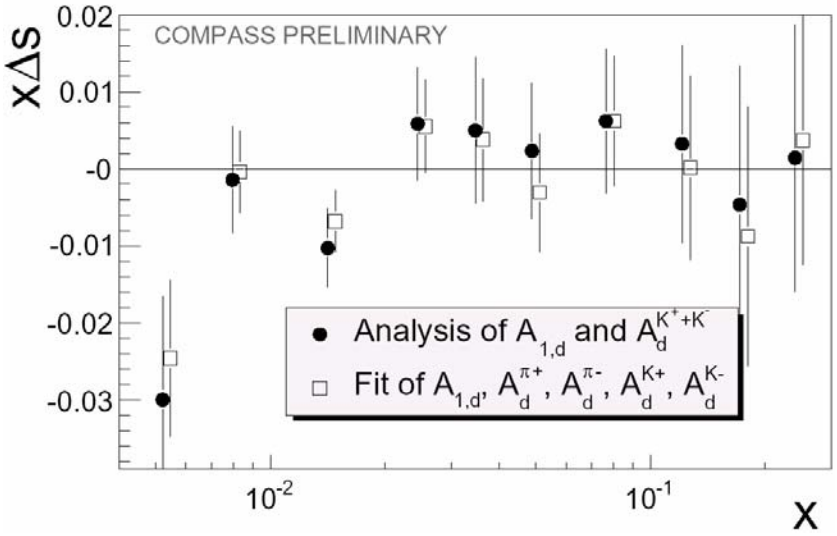
Δs from charged kaon asymmetry





$$\frac{\Delta s}{s} = A_1^d + \left(A_1^{K^+ + K^-} - A_1^d\right)\frac{Q/s + \alpha}{\alpha - 4/5}$$

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

$$R_{UF} = \frac{\int D_d^{K^+}(z)dz}{\int D_u^{K^+}(z)dz} \qquad R_{SF} = \frac{\int D_{\bar{s}}^{K^+}(z)dz}{\int D_u^{K^+}(z)dz}$$

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

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

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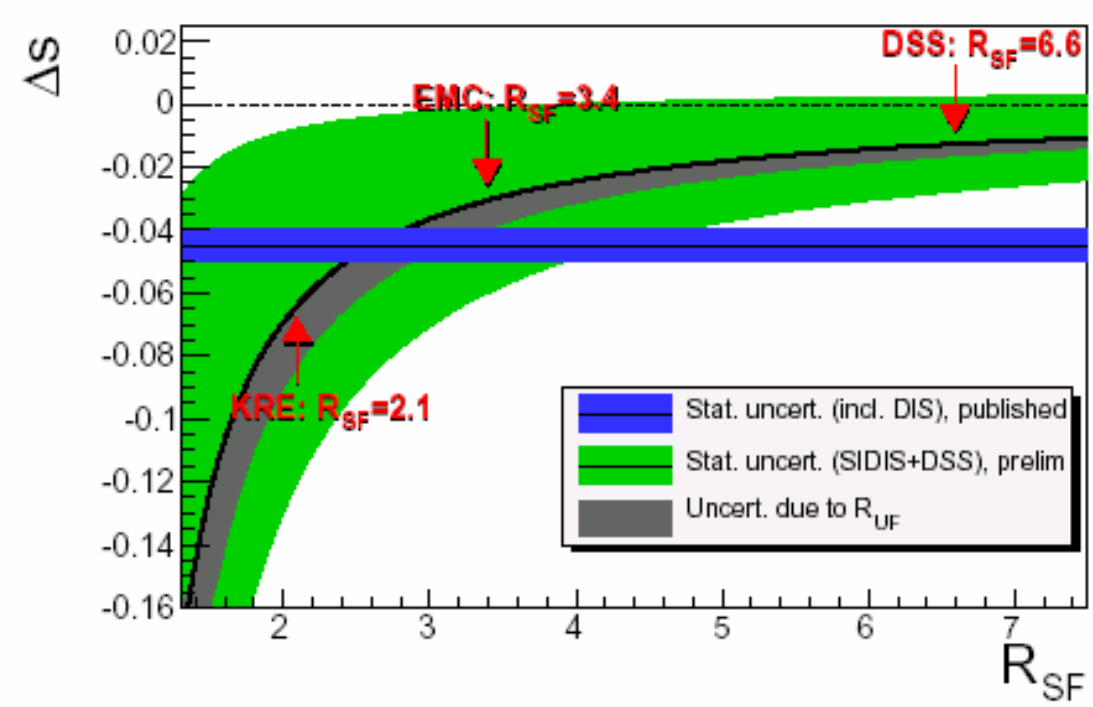
Δs as a function of R_{SF}



$$R_{SF} = \frac{\int D_{\bar{s}}^{K^+}(z)dz}{\int D_{u}^{K^+}(z)dz}$$

$$R_{UF} = \frac{\int D_{d}^{K^+}(z)dz}{\int D_{u}^{K^+}(z)dz}$$

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

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Conclusions

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

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

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

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

Prospects:

Analysis of COMPASS proton data for flavour separation

Extraction of RUF and RSF from COMPASS data on $\sigma_{K^-}/\sigma_{K^+}$

Next-to-Leading Order analysis

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Spares

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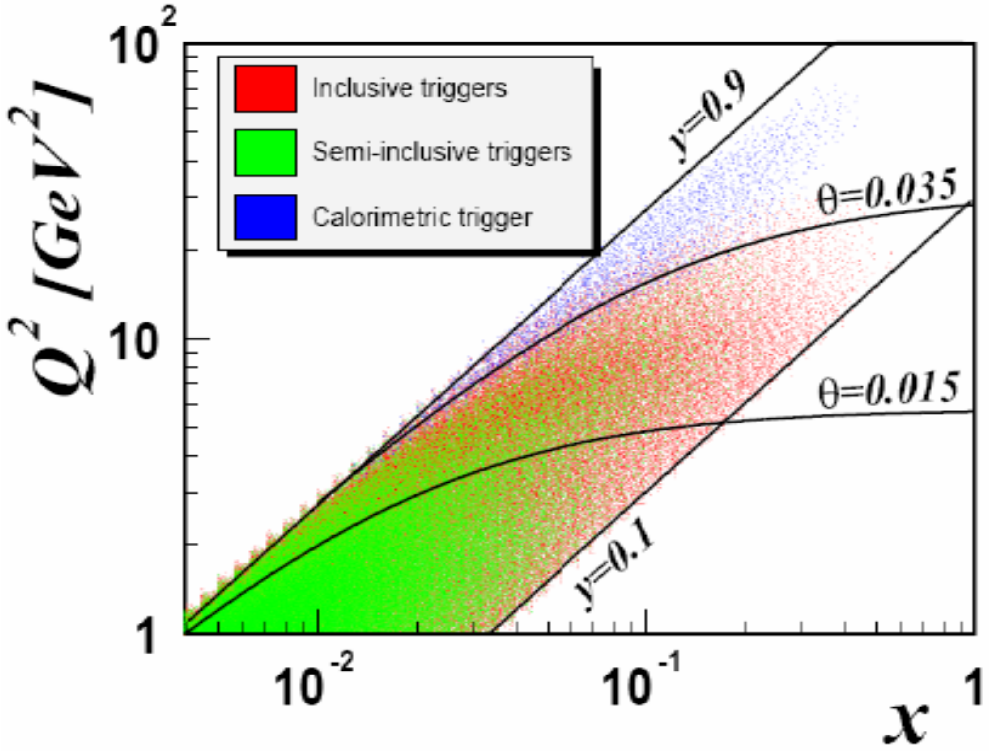
COMPASS Kinematic Domain



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

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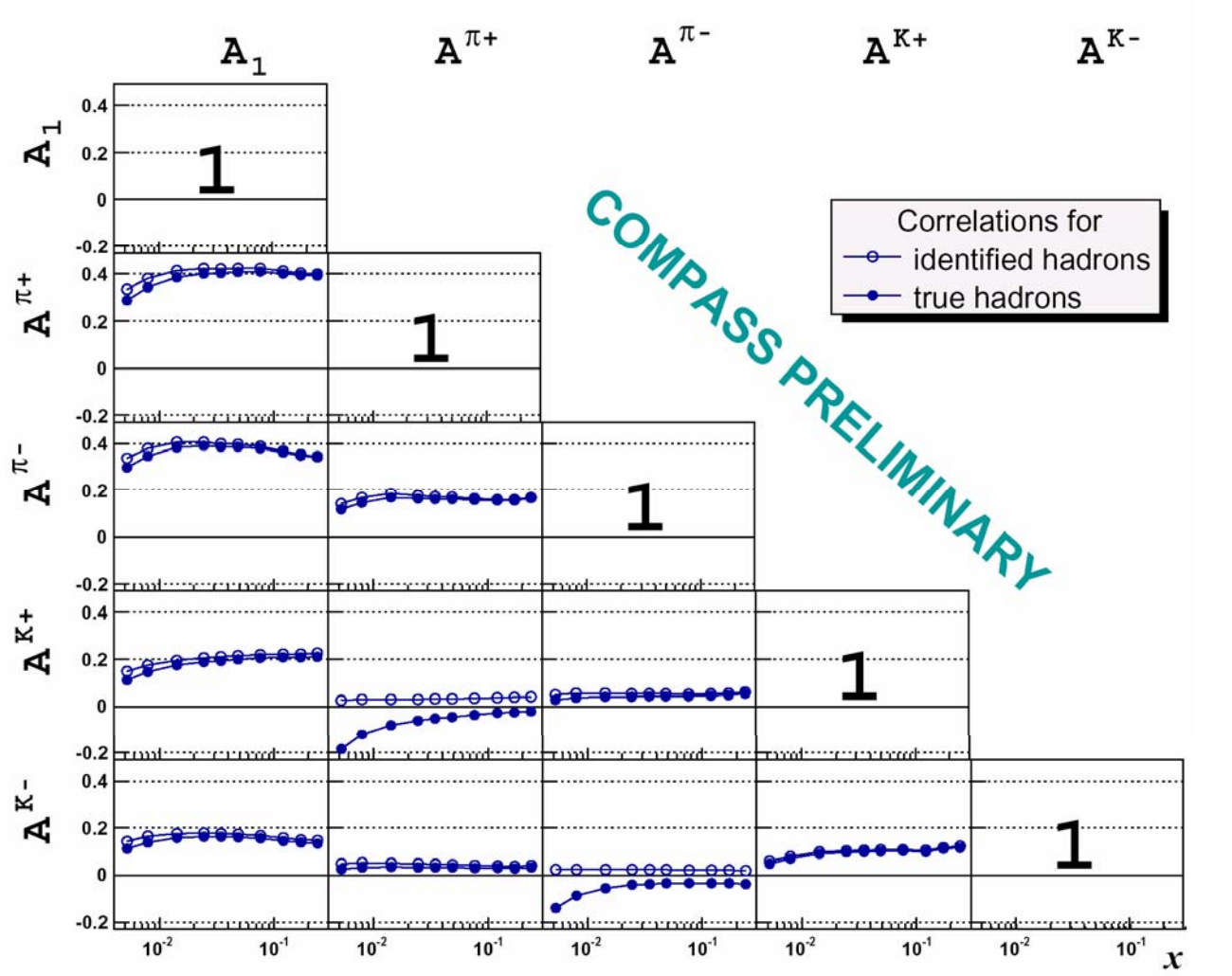
Correlations



Asymmetry correlation matrices, before and after unfolding

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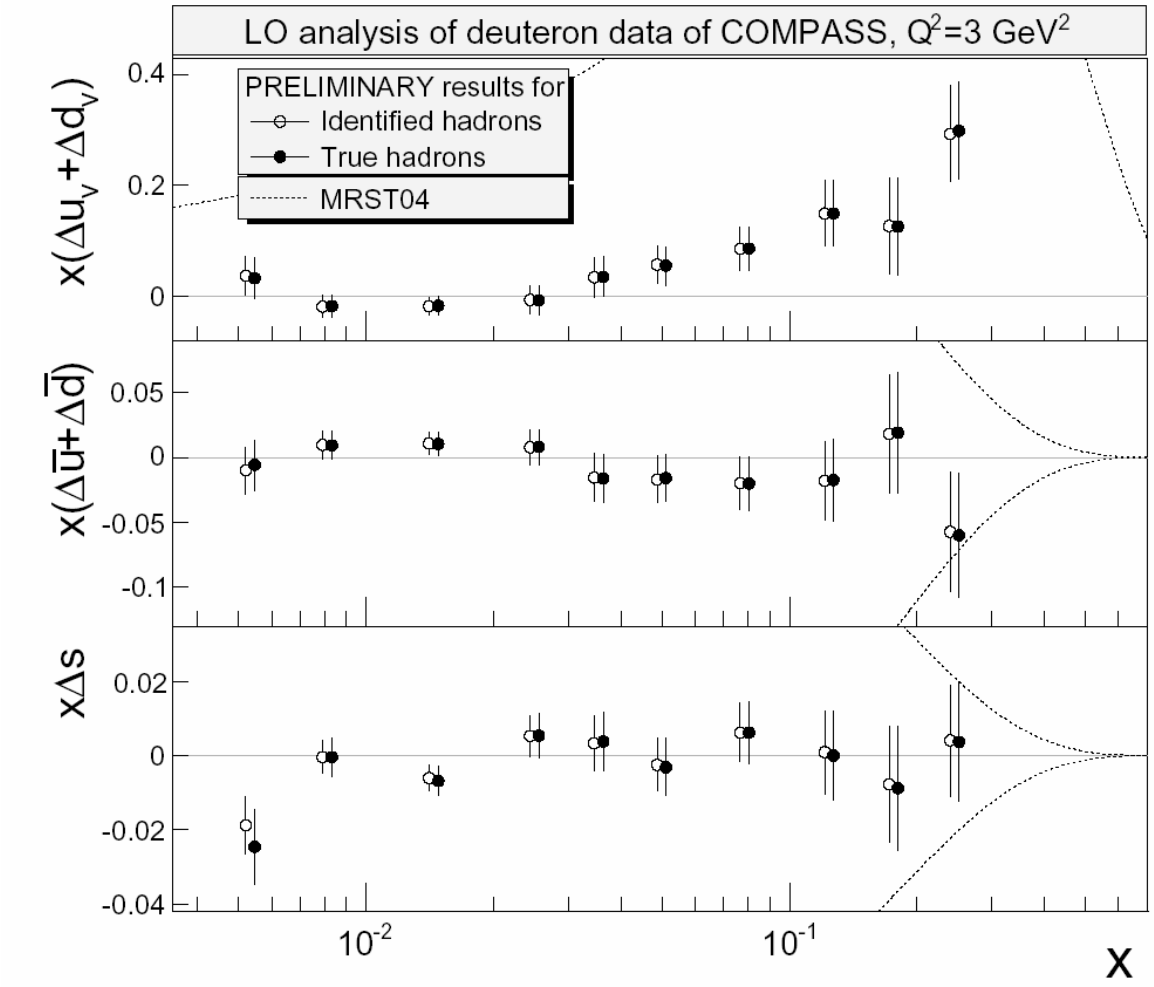
PDFs before and after unfolding



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