New Results from COMPASS

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COMPASS
Großgeräte der physikalischen
Grundlagenforschung

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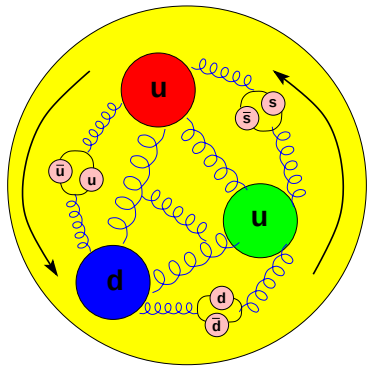
Motivation: Nucleon spin puzzle

$$S_N = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$



Accessible in

$\Delta\Sigma$, Δs	inclusive DIS
Δu,Δd,Δs	semi-inclusive DIS
ΔG	PGF in DIS
L_q	DVCS

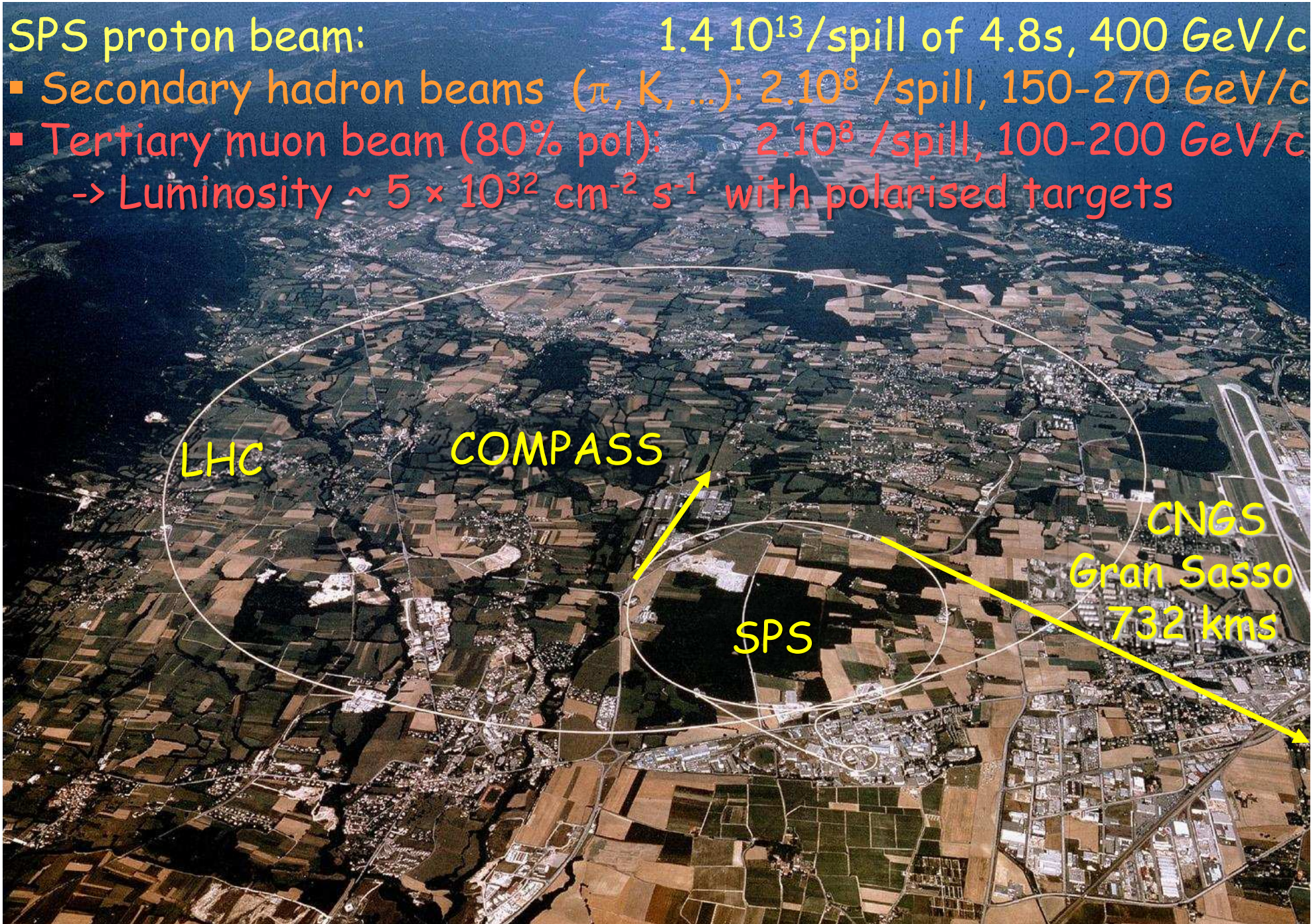
Content

- COMPASS experiment
- Spin structure functions
- Gluonpolarisation
- Quarkpolarisation
- Fragmentation functions

SPS proton beam: 1.4 10^{13}/spill of 4.8s, 400 GeV/c

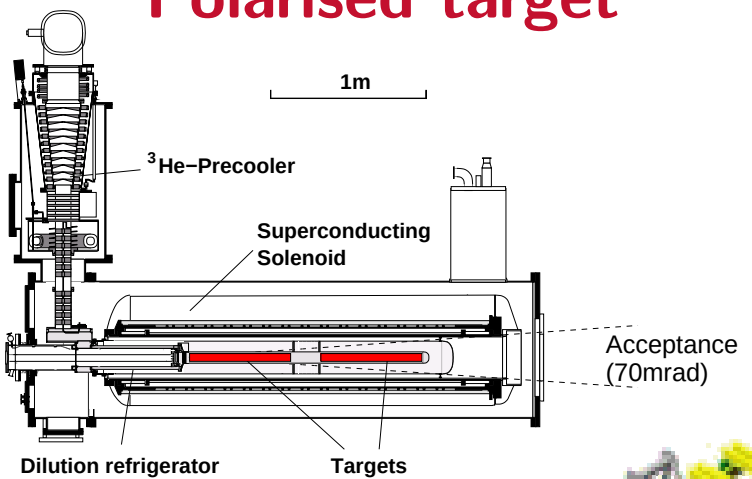
- Secondary hadron beams (π, K, ...): 2.10^{8} /spill, 150-270 GeV/c
- Tertiary muon beam (80% pol): 2.10^{8} /spill, 100-200 GeV/c

  -> Luminosity ~ 5 × 10^{32} cm^{-2} s^{-1} with polarised targets



COMPASS experiment

Polarised target



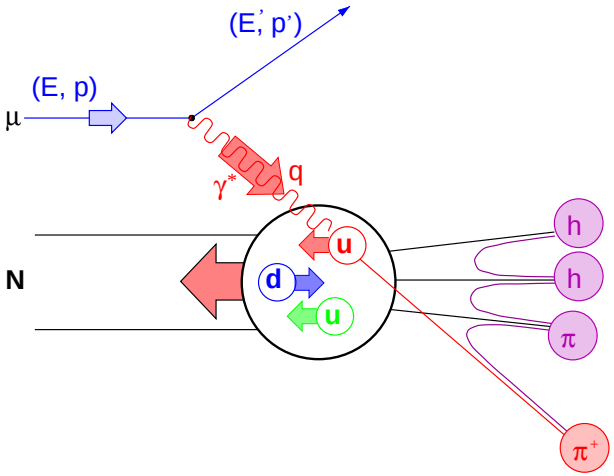
target material: ^{6}LiD, NH_3

polarisation: 50%, 90%

Spectrometer

- Two magnets (1 Tm, 4.5 Tm)
- Tracking ($p > 0.5$ GeV/c)
- PID: π, K, p (RICH)
- ECAL, HCAL, muon filter

Deep inelastic scattering



$$Q^2 = -q^2 \qquad z = E_h/\nu$$
$$\nu = E - E' \qquad p_T^h : \text{transverse}$$
$$x = Q^2/2M\nu \qquad \text{momentum}$$

$$q(x) = q(x)^+ + q(x)^- \quad + \text{ quark } \uparrow\uparrow \text{ nucleon}$$
$$\Delta q(x) = q(x)^+ - q(x)^- \quad - \text{ quark } \downarrow\uparrow \text{ nucleon}$$

- **photon nucleon asymmetry**

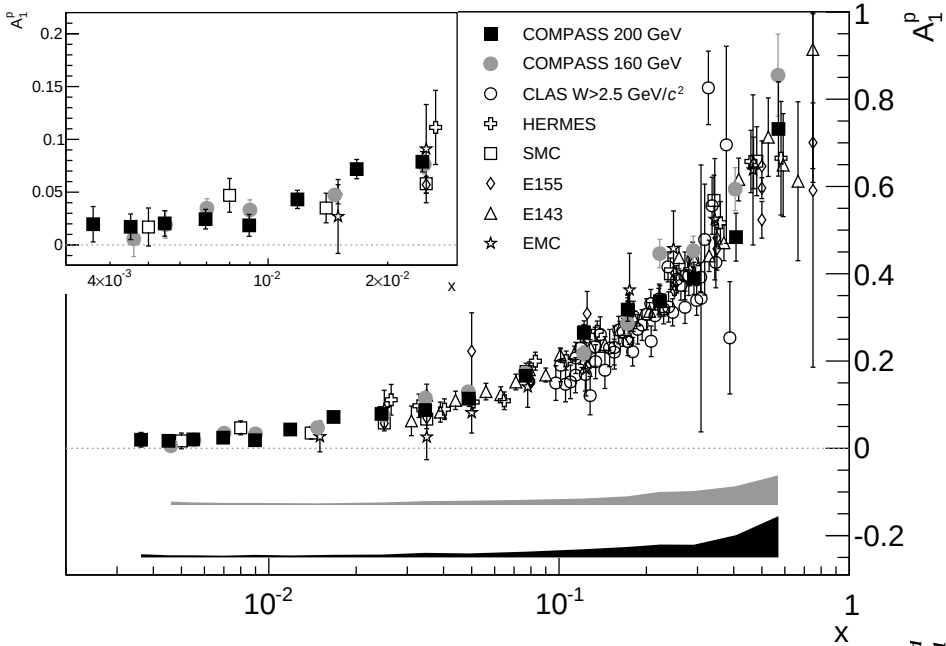
$$A_1 = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} \approx \frac{\Sigma_q\ e_q^2\ (q(x)^+ - q(x)^-)}{\Sigma_q\ e_q^2\ (q(x)^+ + q(x)^-)} = \frac{g_1(x)}{F_1(x)}$$

- **spin structure function**

$$g_1 = \frac{1}{2}\Sigma_q\ e_q^2\ \Delta q(x) = A_1 \cdot \frac{F_2}{2x(1+R)} \approx \frac{A_\parallel}{D} \cdot \frac{F_2}{2x(1+R)}$$

Asymmetry results

hep-ex/1503.08935



- new COMPASS results for A_1^p (200 GeV)
- Kinematic domain:

$$Q^2 > 1\ (\mathrm{GeV}/c)^2$$
$$0.1 < y < 0.9$$
$$0.004 < x < 0.7$$

- world data for A_1^p and A_1^d
- in addition A_1^n from ^{3}He available
- weak Q^2 dependence of A_1

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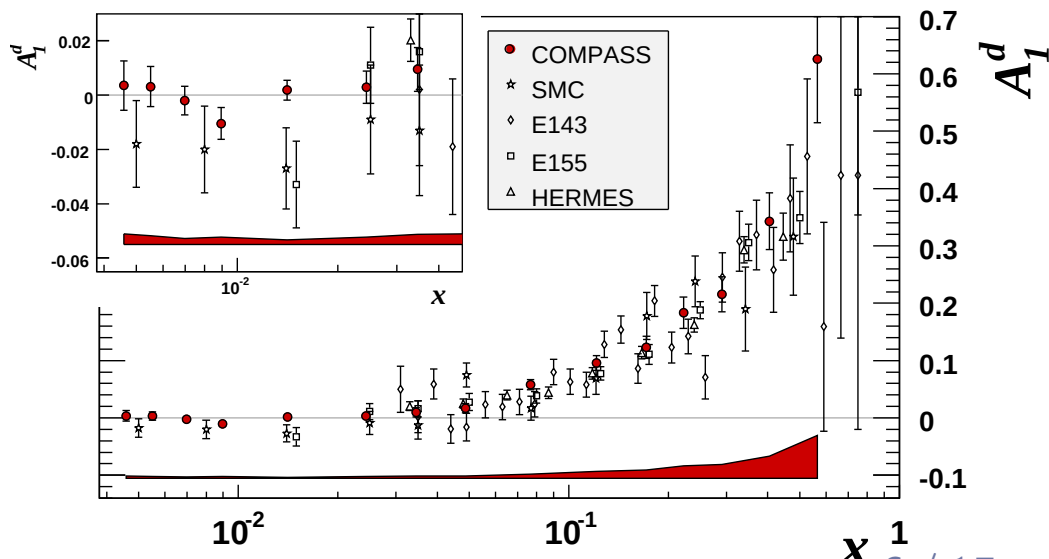
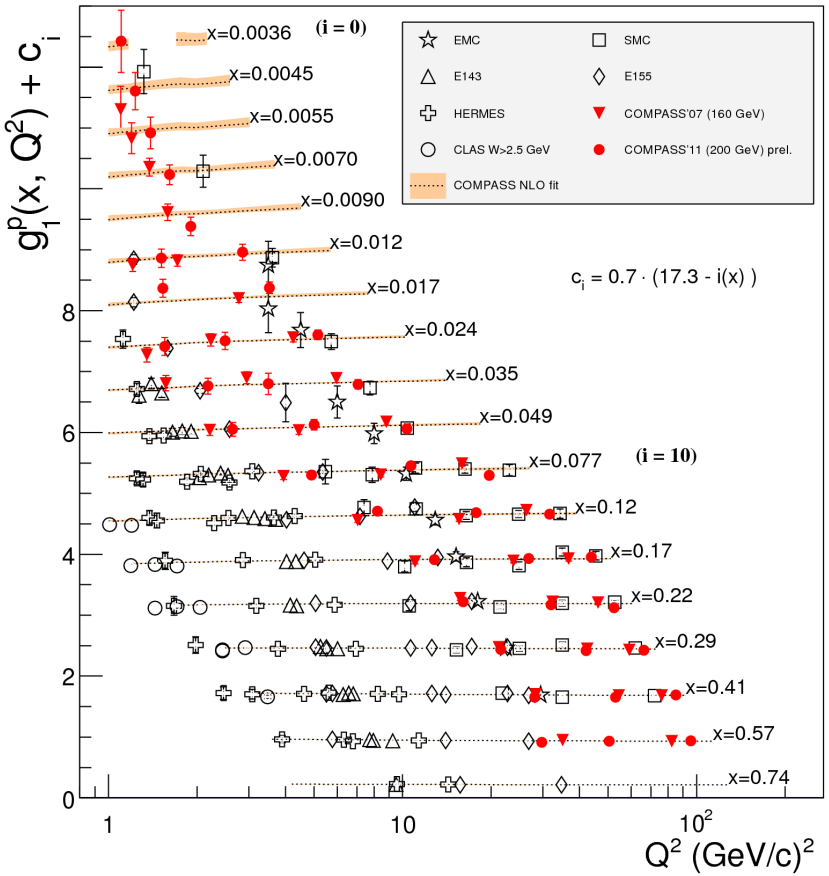
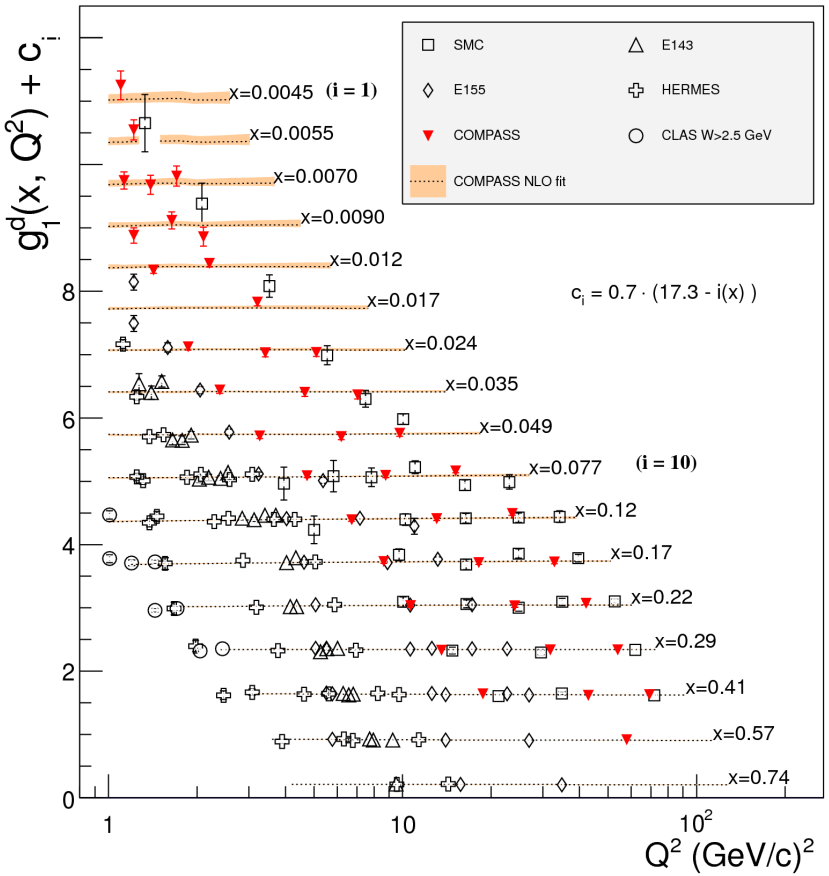


World data for spin structure functions

Proton

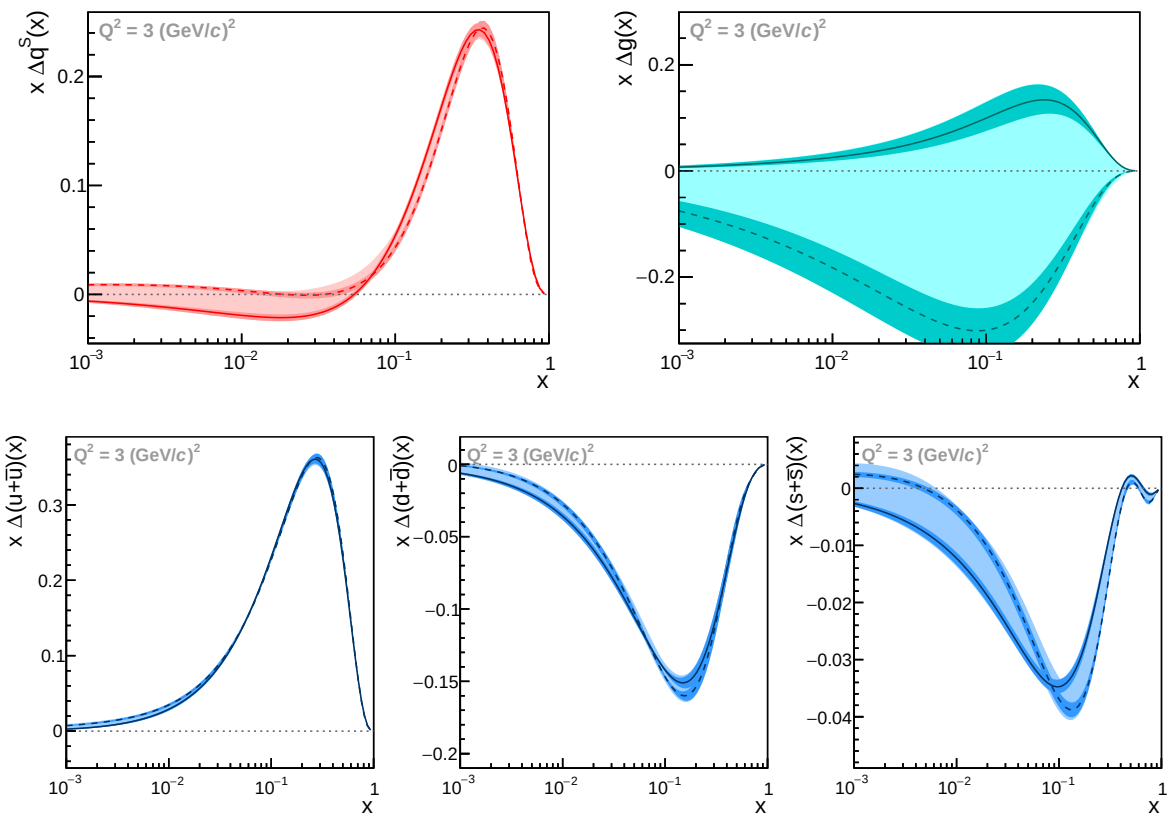


Deuteron



- good coverage in x and Q^2
- NLO pQCD analysis of proton, deuteron and neutron (^{3}He) data
- detailed study of systematics related to functional form

Polarised PDFs at $Q^2 = 3\ (\mathrm{GeV}/c)^2$

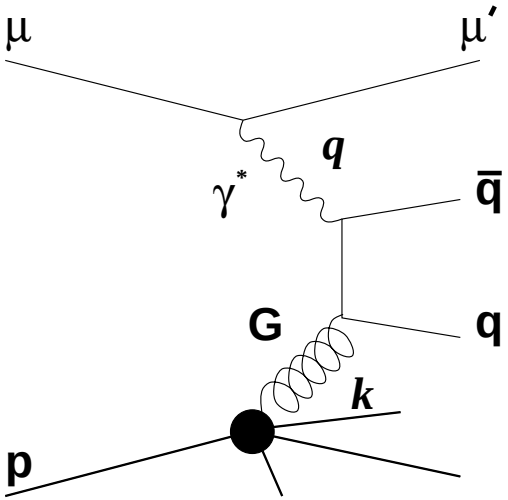


- quark contribution $0.26 < \Delta\Sigma < 0.36$
- strange quark contribution small and negative
- gluon contribution $\Delta G = \int \Delta g(x)\mathrm{d}x$ not well constrained

$$\Longrightarrow \quad \textbf{direct measurement needed}$$

Direct measurements of gluon polarisation

Photon gluon fusion

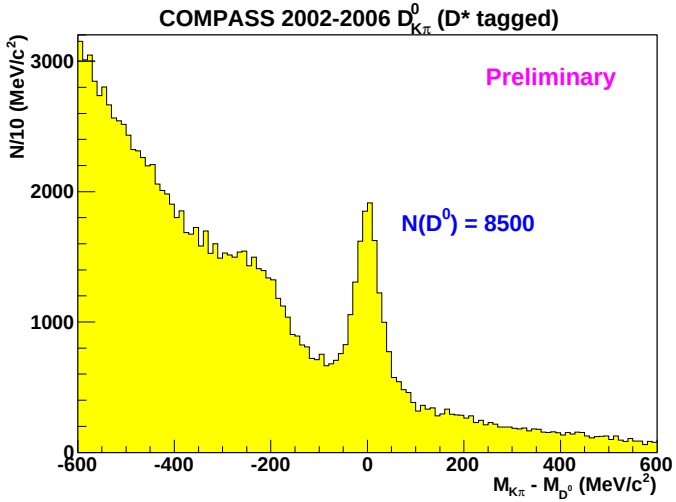


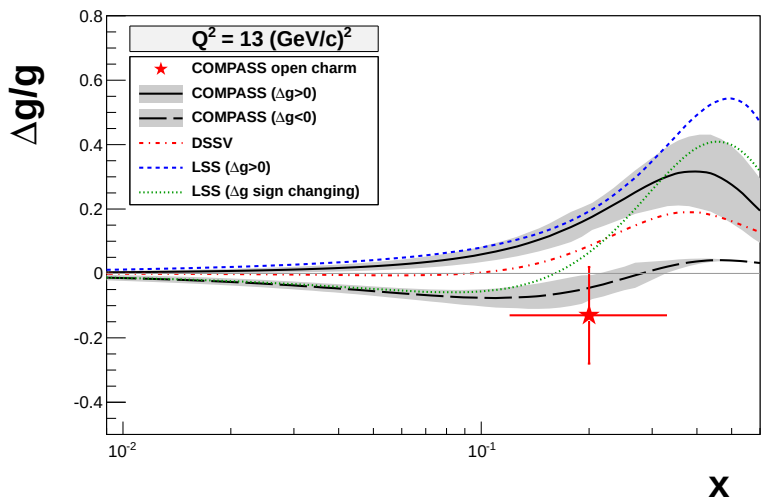
$$A_{\gamma N}^{PGF} = \frac{\int d\hat{s}\, \Delta\sigma^{PGF}\, \Delta G(x_g, \hat{s})}{\int d\hat{s}\, \sigma^{PGF}\, G(x_g, \hat{s})} \approx \langle a_{LL}^{PGF} \rangle \frac{\Delta G}{G}$$

$\langle a_{LL}^{PGF} \rangle$ analysing power

Open charm production

$$\gamma g \to c\bar{c} \to D^0, D^*$$



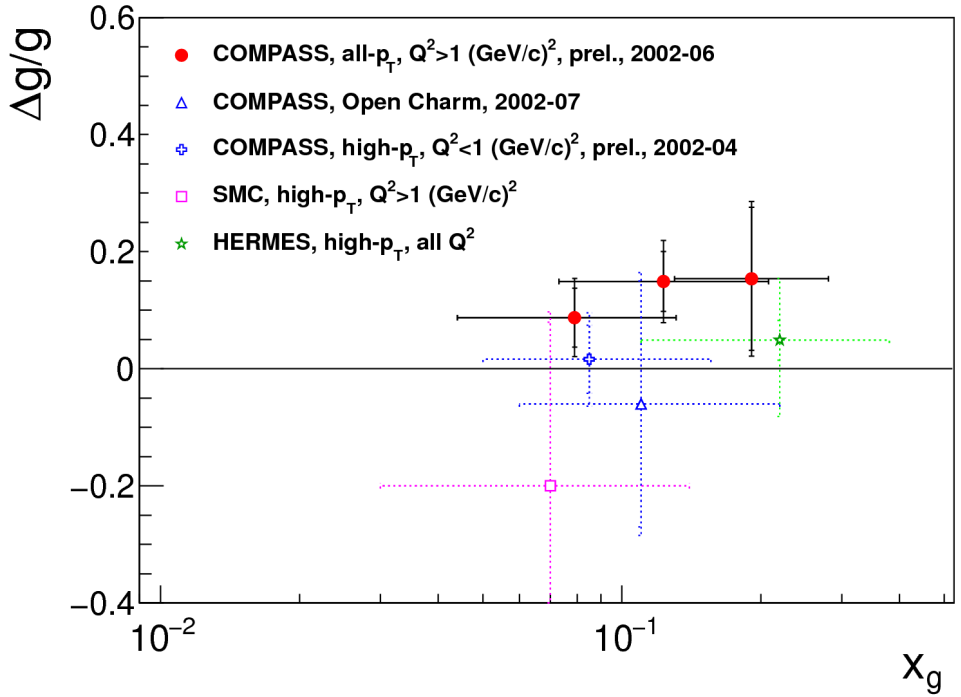


$$\Delta g/g^{NLO} = -0.13 \pm 0.15_{stat} \pm 0.15_{syst}$$

LO Results for gluon polarisation

High p_T hadrons (pairs): $\gamma g \to q\bar{q} \to H^+H^-$ or H

- high statistics
- but contributions from several background processes
- estimated from MC simulation
- neural network to disentangle processes



- new analysis: single hadron production
- simultaneous extraction of leading process and PGF asymmetry

$$\Delta g/g^{\mathrm{LO}} = 0.113 \pm 0.038_{\mathrm{stat}} \pm 0.035_{\mathrm{syst}}$$

- first direct measurement of positive $\Delta g/g$, results also in 3 bins

Quark polarisations from SIDIS

Basic concept

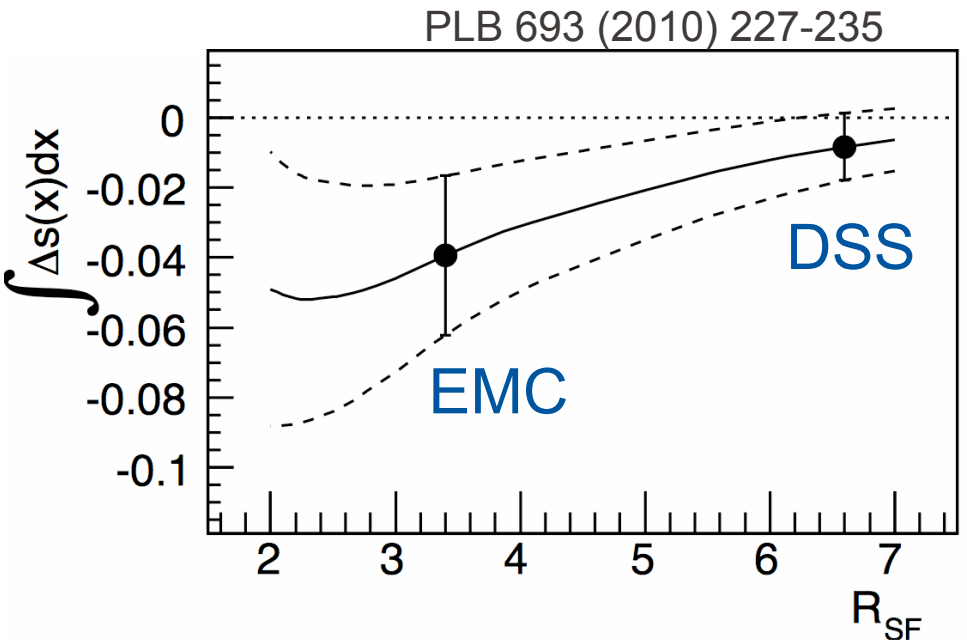
measured:

A_1^{d}, $A_{1\mathrm{d}}^{K^\pm}$, $A_{1\mathrm{d}}^{\pi^\pm}$, A_1^{p}, $A_{1\mathrm{p}}^{K^\pm}$, $A_{1\mathrm{p}}^{\pi^\pm}$

determined:

Δu, $\Delta\bar{u}$, Δd, $\Delta\bar{d}$, Δs, $\Delta\bar{s}$

$$A_1^h = \frac{\Sigma_q e_q^2 (\Delta q(x) \int D_q^h(z)\mathrm{d}z}{\Sigma_q e_q^2 q(x) \int D_q^h(z)\mathrm{d}z}$$



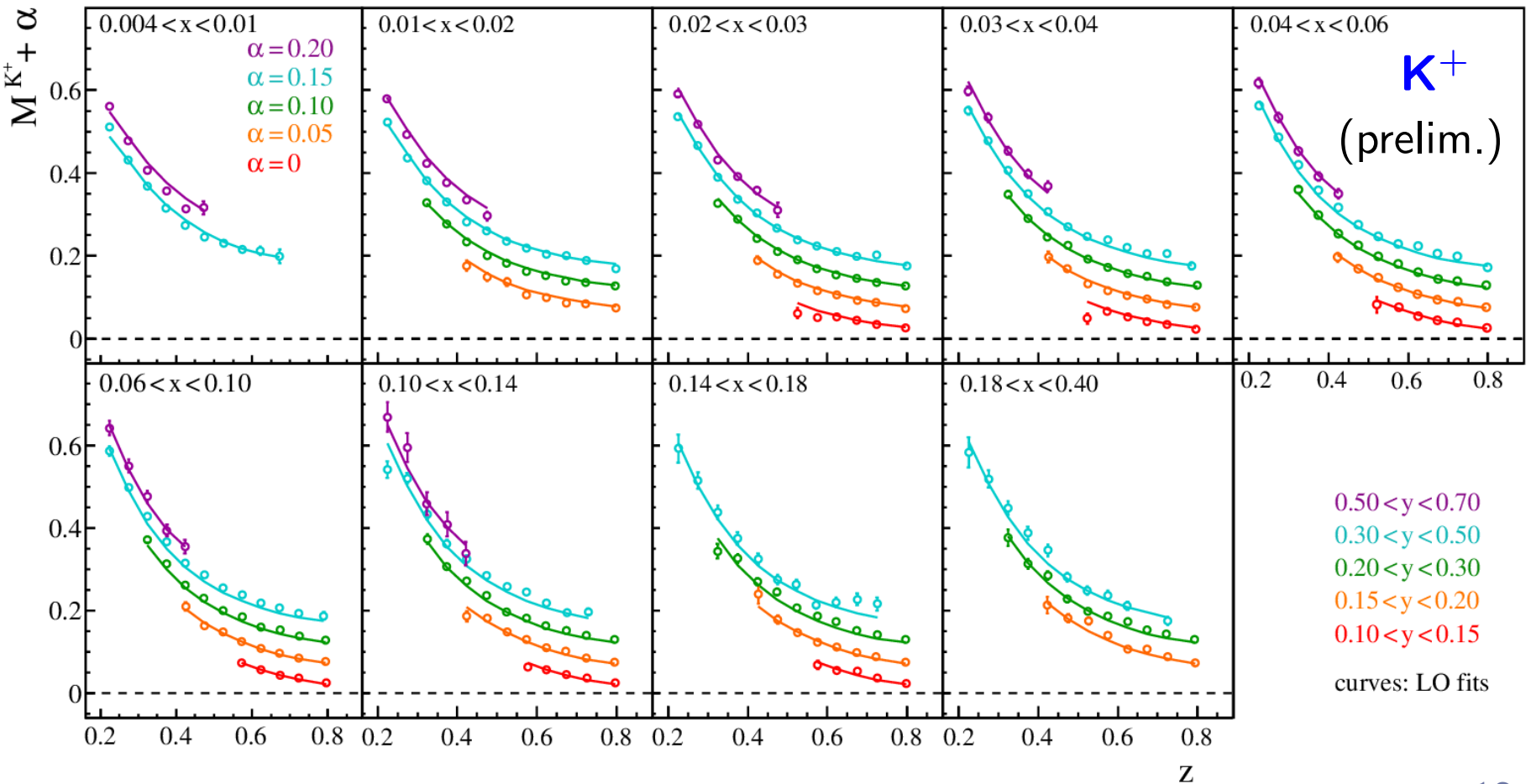
- large dependence on

$$R_{SF} = \frac{\int D_{\bar{s}}^{K^+}(z)\mathrm{d}z}{\int D_u^{K^+}(z)\mathrm{d}z}$$

- measurement of kaon FFs neccessary

Kaon multiplicities

$$M_{\mathrm{h}}(x, Q^2, z) = \frac{1}{N_{\mathrm{DIS}}(x, Q^2)} \frac{\mathrm{d}N_{\mathrm{h}}(x, Q^2, z)}{\mathrm{d}z} = \frac{\sum_q e_q^2 q(x, Q^2) D_q^{\mathrm{h}}(z, Q^2)}{\sum_q e_q^2 q(x, Q^2)}$$



LO QCD analysis

- results for charged pions and kaons from isoscalar target
- for kaons data still final radiative corrections pending
- determination of favoured and unfavoured fragmentation functions
- for pions:

$$D^{\pi}_{\mathrm{fav}} = D^{\pi^+}_{u} = D^{\pi^-}_{d}$$

$$D^{\pi}_{\mathrm{unf}} = D^{\pi^+}_{\bar{u}} = D^{\pi^-}_{\bar{d}} = D^{\pi^-}_{s} = ...$$

- for kaons:

$$D^{K}_{\mathrm{fav}} = D^{K^+}_{u} = D^{K^-}_{d}$$

$$D^{K}_{\mathrm{unf}} = D^{K^+}_{\bar{u}} = D^{K^-}_{\bar{d}} = D^{K^+}_{s} = ...$$

$$D^{K}_{\mathrm{str}} = D^{K^+}_{\bar{s}} = D^{K^-}_{s}$$

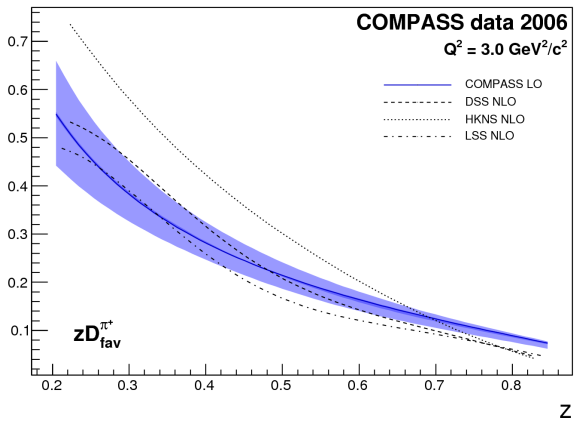
- unpolarised PDFs from MSTW08
- results for favoured and unfavoured FFs stable, strange FF still under investigation

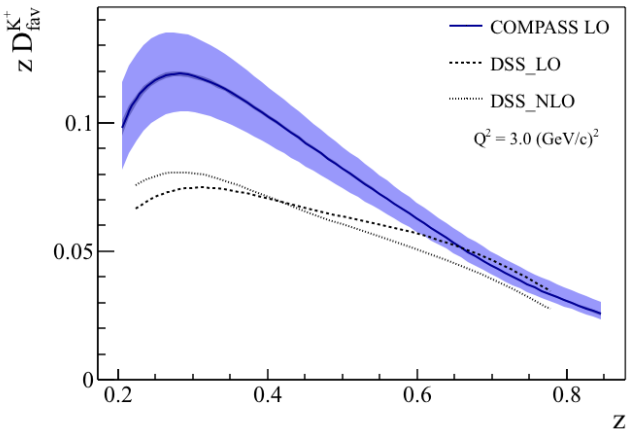
LO fragmentation functions (preliminary)

pions

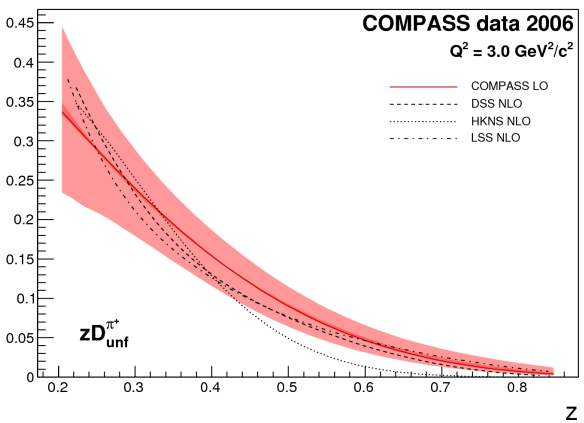
kaons

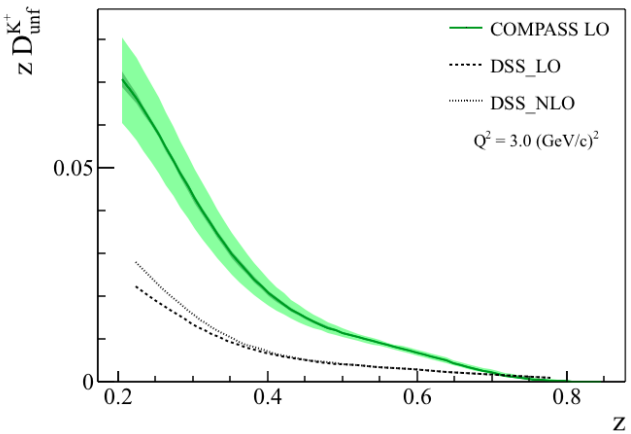
D_{fav}





D_{unf}





- for pions agreement with recent NLO FFs observed
- for kaons favoured and unfavoured FF are considerable larger

Outlook

Ongoing

- Analysis of K^0 multiplicities
- Analysis of 2012 hydrogen data
- Transverse momentum dependent multiplicities
- Current data taking: Drell-Yan with polarised target for transverse momentumg dependent distributions

Future

- Data taking with hydrogen target in 2016/7
- Investigation of orbital angular momentum via deeply virtual Compton scattering
- In parallel:
  SIDIS measurements for multiplicities $M^h(x, Q^2, z, p_T, \phi)$ and transverse momentumg dependent distribution