Longitudinal spin-dependent quark distributions from DIS at COMPASS

Recent COMPASS@CERN results on inclusive and semi-inclusive muon-deuteron asymmetries in deep inelastic scattering ..
.. and what does one learn from them.

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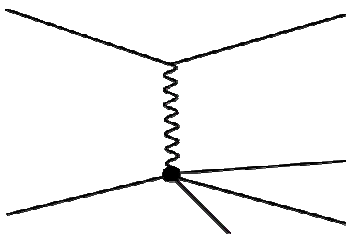
What and why to measure

- *One needs polarized target and beam to measure spin-dependent quark distributions*
- *On isoscalar target only u+d can be accessed*
- *One needs final-state hadrons to separate val from sea*



What and why to measure: cross section asymmetries

Inclusive

$$A_1 = \frac{\sigma_0 - \sigma_2}{\sigma_0 + \sigma_2}$$

In QPM, for deuteron target, *u and d* quarks and antiquarks contribute equally

$$A_1^d = \frac{(e_u^2+e_d^2)(\Delta u+\Delta\bar{u}+\Delta d+\Delta\bar{d})+2e_s^2(\Delta s+\Delta\bar{s})}{(e_u^2+e_d^2)(u+\bar{u}+d+\bar{d})+2e_s^2(s+\bar{s})}$$

What and why to measure: cross section asymmetries, cont.

Semi-Inclusive: quarks and antiquarks do not contribute equally for difference in fragmentation likelihood, e.g.

$$D_u^{\pi^+} > D_{\bar{u}}^{\pi^+}$$

Allows for valence *vs.* sea separation

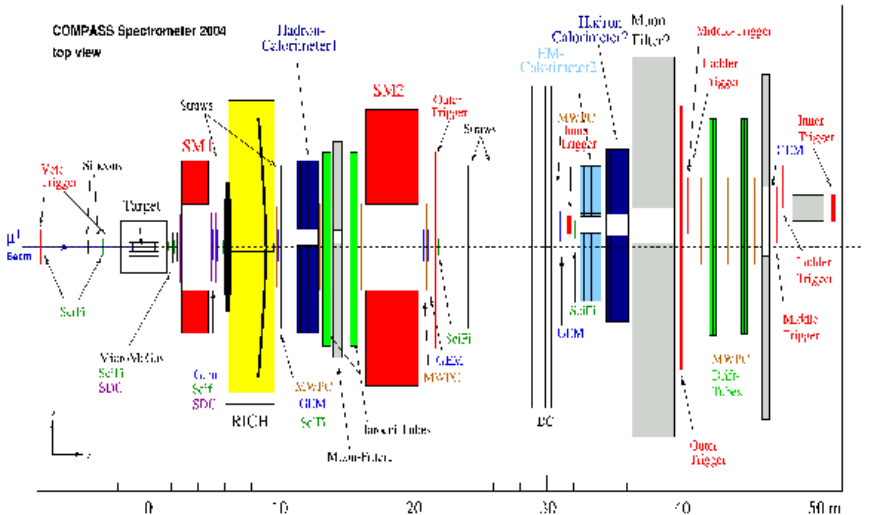
What and why to measure: cross section asymmetries, cont.

Semi-Inclusive: for the “h+”-”h-” difference asymmetries only valence quarks contribute.

Particularly simple in LO QCD for isoscalar target; fragmentation functions do not enter at all

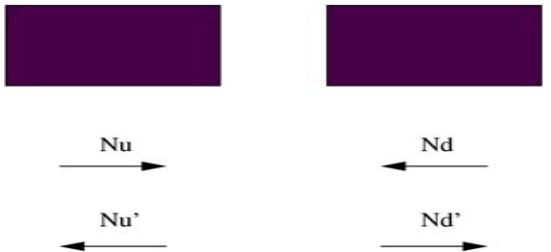
$$A_d^{h^+-h^-} = \frac{\Delta u_v + \Delta d_v}{u_v + d_v}$$

200M muons/spill, 4.8/16.2 s, 160 GeV/c, P=-76%



Estimators for asymmetries

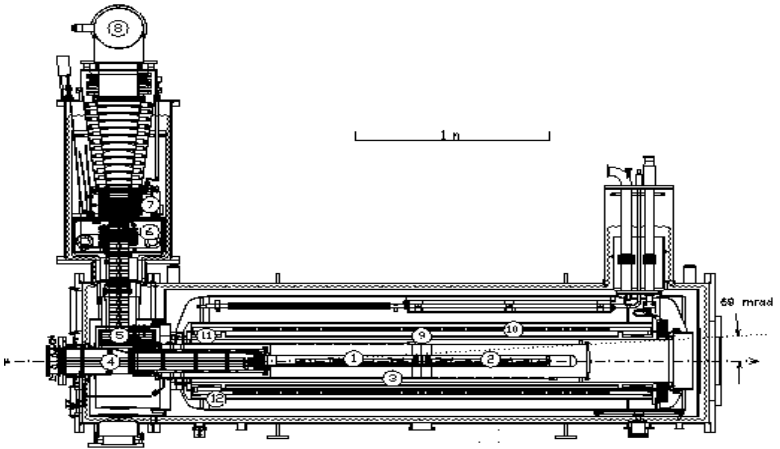
Twin target configuration, reversing polarization every 8 hours



$$A_{\parallel} = \frac{1}{f P_T P_B}\left(\frac{N_u - N_d}{N_u + N_d} + \frac{N'_u - N'_d}{N'_u + N'_d}\right) \qquad A_1 = A_{\parallel}/D$$

COMPASS polarized target

Li D, P=50%, f=0.38



COMPASS statistics 2002-04

$$Q^2 > 1\,\mathrm{GeV}^2 (DIS), 0.1 < y < 0.9 (rad.corr.), 0.004 < x < 0.7$$

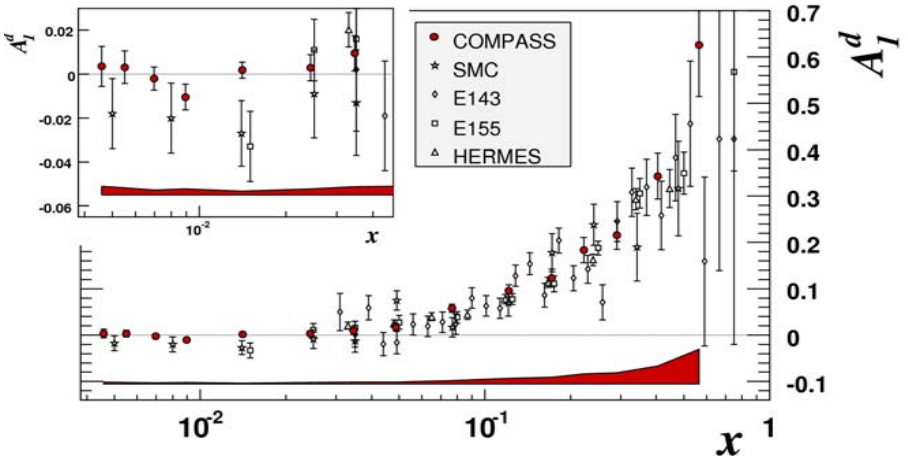
47 million DIS events

- 0.2 (target fragm.) <z<0.85 (exclusive diff.)

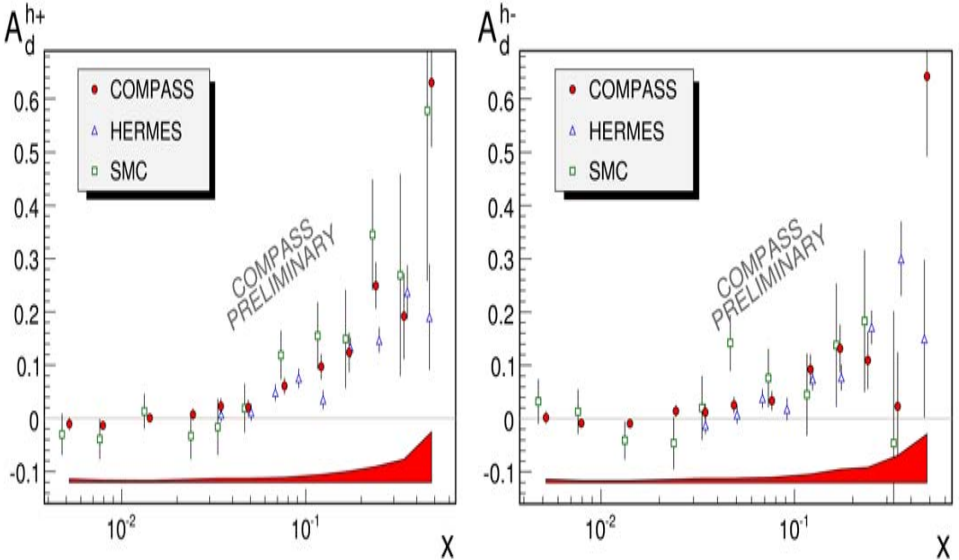
30 million had+, 25 million had-

No particle identification from RICH used yet

Asymmetries results



Asymmetries results, cont.



COMPASS difference asymmetries

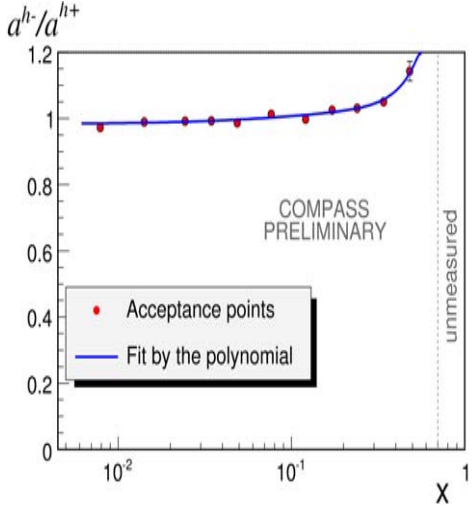
$$A^{h^+-h^-} = \frac{1}{1-r}\left(A^{h^+} - rA^{h^-}\right)$$

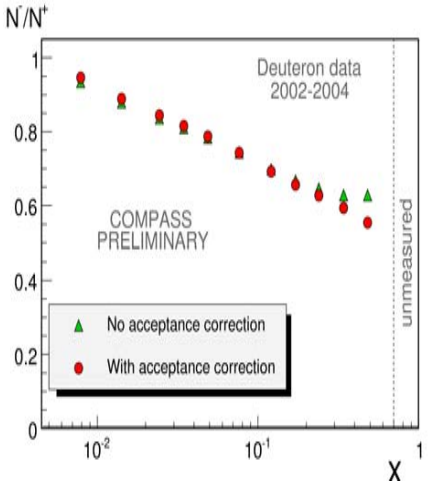
1/0 expression at r=1; restrict to x>0.006

$$r = \frac{\sigma^{h^-}}{\sigma^{h^+}} = \frac{N^-/a^-}{N^+/a^+}$$

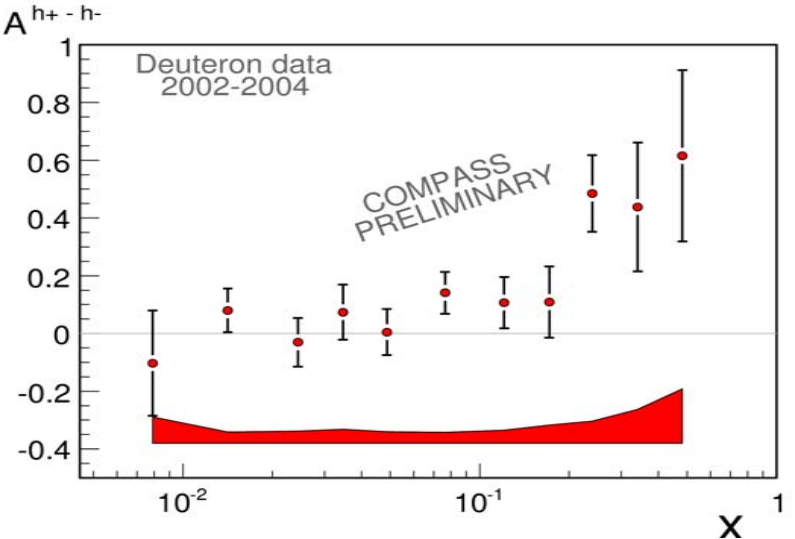
Acceptance determined using MC

Acceptance ratio





Difference asymmetry

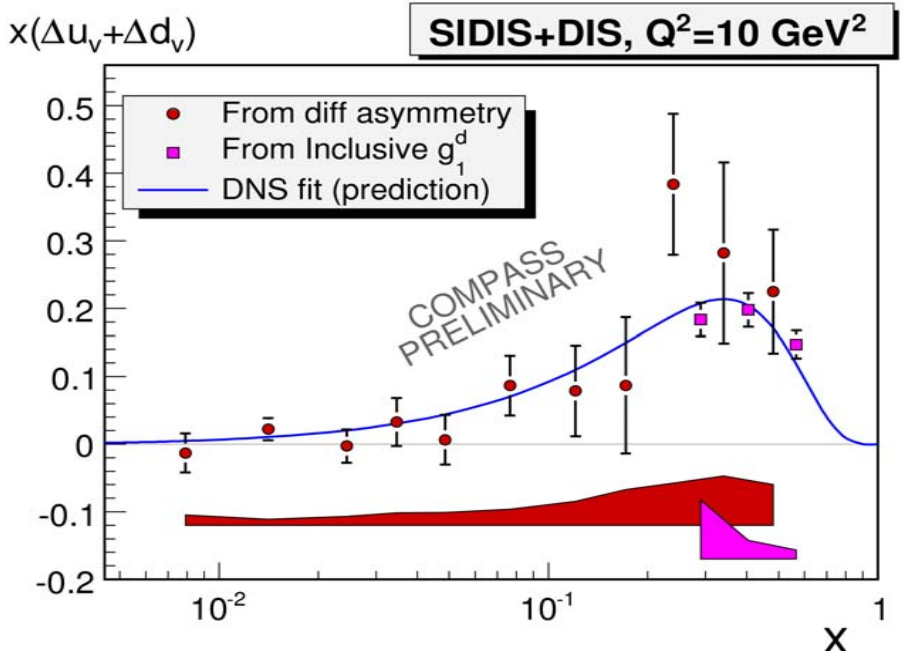


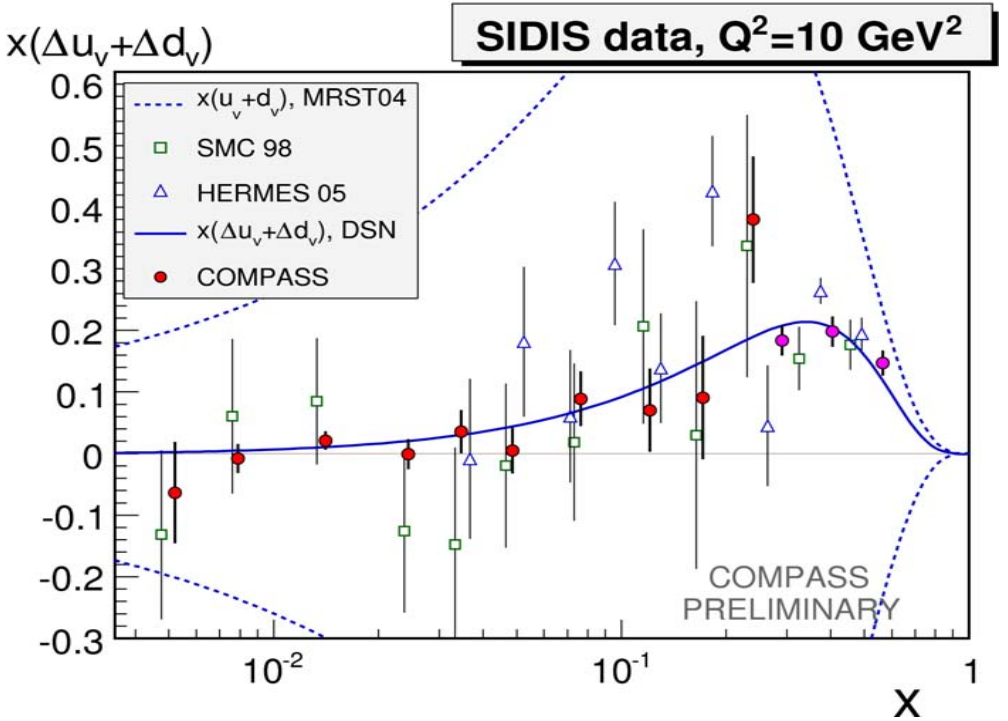
Spin-dependent valence quarks

$$\Delta u_v + \Delta d_v = \frac{u_v + d_v}{(1+R)(1-1.5\omega_D)} A_d^{h^+ - h^-}$$

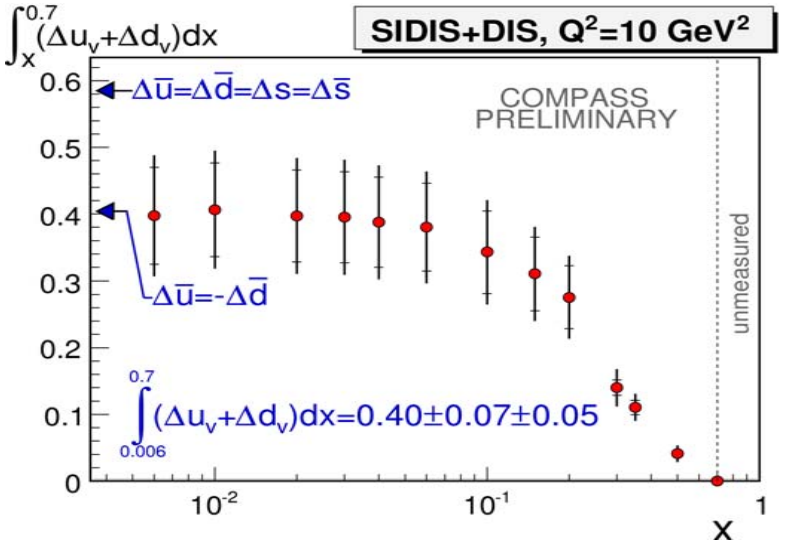
For high x, neglecting sea

$$\Delta u_v + \Delta d_v = \frac{36}{5} \frac{g_1^d}{1-1.5\omega_D}$$


x(Δu_v+Δd_v)
SIDIS+DIS, Q²=10 GeV²
From diff asymmetry
From Inclusive g₁ᵈ
DNS fit (prediction)
COMPASS
PRELIMINARY
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
10⁻²
10⁻¹
1
x


SIDIS data, Q^2=10 GeV^2
$x(\Delta u_v+\Delta d_v)$
$x(u_v+d_v)$, MRST04
SMC 98
HERMES 05
$x(\Delta u_v+\Delta d_v)$, DSN
COMPASS
COMPASS
PRELIMINARY
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
10^{-2}
10^{-1}
1
X

X-integrals


$\int_x^{0.7}(\Delta u_v+\Delta d_v)dx$
SIDIS+DIS, Q^2=10 GeV^2
$\Delta\bar{u}=\Delta\bar{d}=\Delta s=\Delta\bar{s}$
COMPASS
PRELIMINARY
$\Delta\bar{u}=-\Delta\bar{d}$
unmeasured
$\int_{0.006}^{0.7}(\Delta u_v+\Delta d_v)dx=0.40\pm0.07\pm0.05$
0.6
0.5
0.4
0.3
0.2
0.1
0
10^{-2}
10^{-1}
1
x

Unmeasured regions

- x>0.7 contribution estimated using DeFlorian-Navarro-Sassot parametrization to be 0.004
- X<0.006 is negligible

Systematic errors

- Standard contributions to asymmetries (beam and target polarizations, D, f) amount to 8%
- Radiative corrections: < 0.001 for any x
- False asymmetries studied by using different grouping of data: about 0.5 of statistical error

X-integrals

- Non-strange sea can be determined using

$$\Delta\bar{u} + \Delta\bar{d} = 3\Gamma_1^N - \frac{1}{12}\Gamma_v + \frac{1}{12}a_8$$

Integrals over 0<x<1: $\Gamma_{1(v)}$

Octet axial current matrix element: a_8

X-integrals, values

	x-range	Q^2 $(\mathrm{GeV}/c)^2$	$\Delta u_v + \Delta d_v$		$\Delta\bar{u} + \Delta\bar{d}$	
			Exp. Value	DNS	Exp. Value	DNS
SMC	0.003 0.7	10	$0.26 \pm 0.21 \pm 0.11$	0.386	$0.02 \pm 0.08 \pm 0.06$	−0.009
HERMES	0.023 0.6	2.5	$0.43 \pm 0.07 \pm 0.06$	0.363	$-0.06 \pm 0.04 \pm 0.03$	−0.005
COMPASS	0.006 0.7	10	$0.40 \pm 0.07 \pm 0.05$	0.385		−0.007
	0 1		$0.41 \pm 0.07 \pm 0.05$		$0.0 \pm 0.04 \pm 0.03$	

Conclusions

- High-precision, wide x-range measurement of the valence-quark contribution to the nucleon spin
- The non-strange sea polarization is small; data slightly favour opposite signs for *u and d*

Additional remarks

- From QCD fits to inclusive data $\Delta s = -0.08 \pm 0.03$

Identified kaons: x-dependence, but unlikely to improve integral; analysis underway

- Proton data to separate light flavours (2007)
- NLO analysis needed: sea *vs.* gluons