The strange quark polarization puzzle and the role of fragmentation functions: a status report

The LSS Collaboration

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presented by Elliot Leader

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Topics

- the strange quark polarization in DIS
- the strange quark polarization in SIDIS
- the role of fragmentation functions
- present status of fragmentation functions

the strange quark polarization in DIS

From polarized *inclusive* deep inelastic scattering (DIS) obtain $g_1(x, Q^2)$.
Leading twist part:

$$
\begin{aligned}
g_1(x,Q^2) &= \frac{1}{2}\sum_{flavours} e_q^2 \Big\{ \Delta q(x,Q^2) + \Delta\bar{q}(x,Q^2) \\
&+ \frac{\alpha_s(Q^2)}{2\pi}\int_x^1 \frac{dy}{y}\{\Delta C_q(x/y)\,[\Delta q(y,Q^2) + \Delta\bar{q}(y,Q^2)] \\
&+ \Delta C_G(x/y)\,\Delta G(y,Q^2)\}\Big\}
\end{aligned}
$$

where ΔC_G and ΔC_q are Wilson coefficients

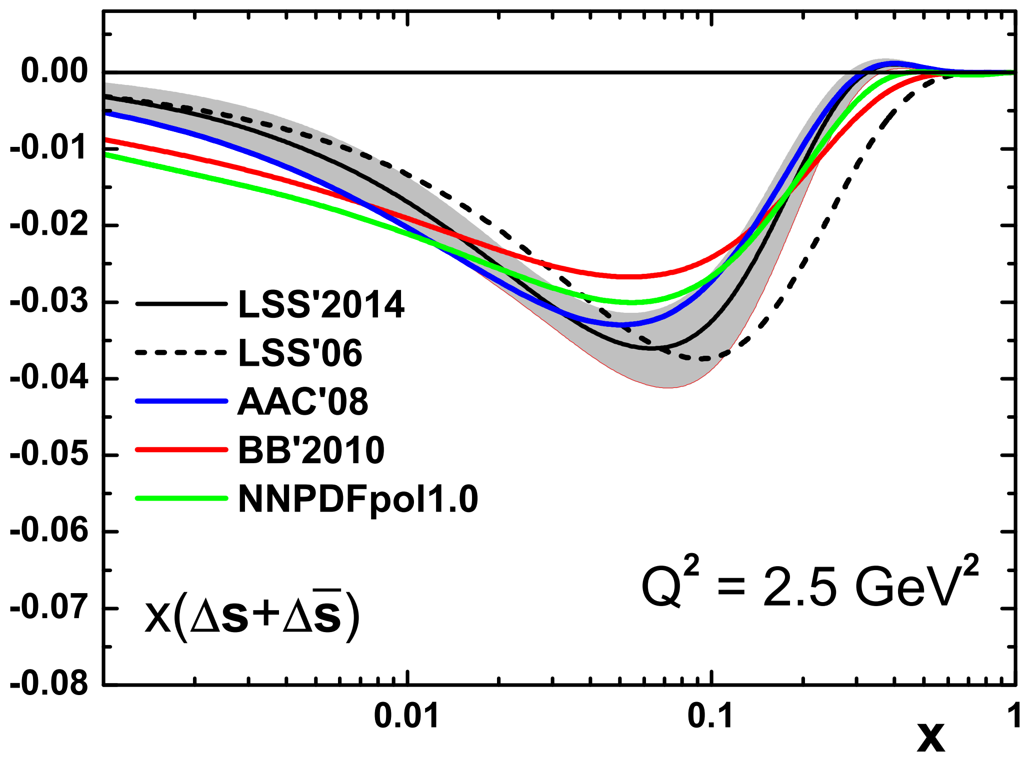
Flavour separation aided by neutron β-decay (a_3) and SU(3) for hyperon β-decay (a_8).

$$a_3 = \int_0^1 dx\ \Delta q_3(x)$$
$$a_8 = \int_0^1 dx\ \Delta q_8(x)$$

$$\Delta q_3 = (\Delta u + \Delta \overline{u}) - (\Delta d + \Delta \overline{d})$$

$$\Delta q_8 = (\Delta u + \Delta \overline{u}) + (\Delta d + \Delta \overline{d}) - 2(\Delta s + \Delta \overline{s})$$

All studies of DIS yield negative values for $\Delta s(x) + \Delta \overline{s}(x)$

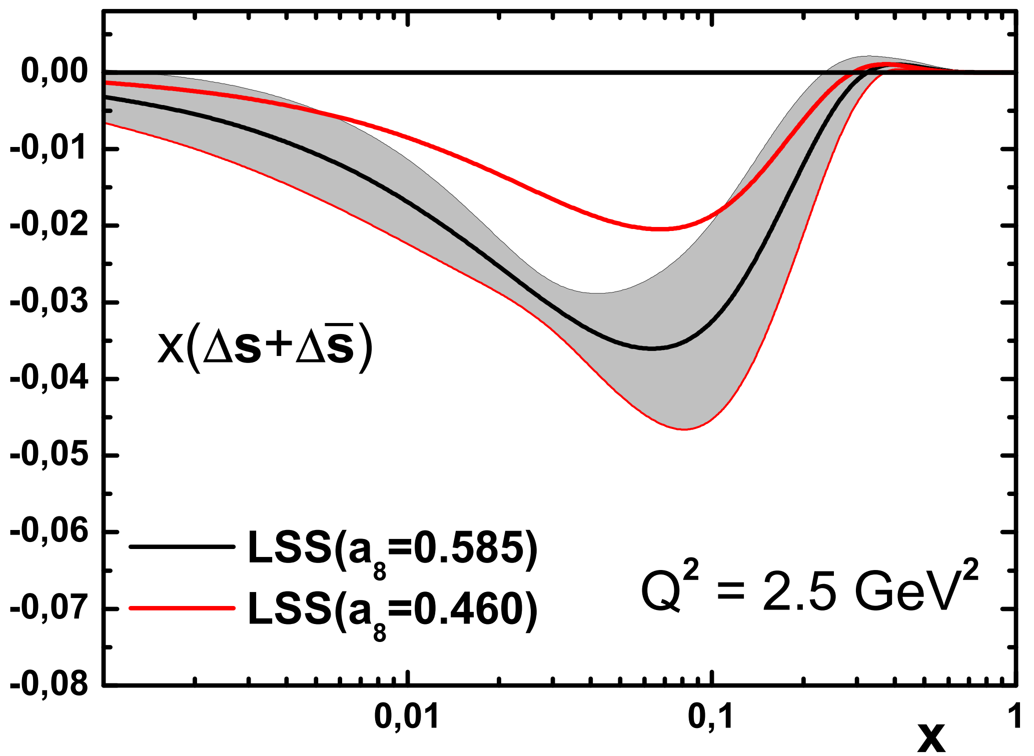


0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
0.01
0.1
1
x
LSS'2014
LSS'06
AAC'08
BB'2010
NNPDFpol1.0
$Q^2 = 2.5$ GeV^2
$x(\Delta s+\Delta\bar{s})$

Note:

1. Our last analysis (2014) [Phys. Rev. D91, 2015, 054017] allowed for a possible sign change in $\Delta s(x) + \Delta\bar{s}(x)$.

2. a_8 was allowed wide range of values. The figure shows the result when a_8 is given the value 0.46, instead of the SU(3) value of 0.585. This corresponds to the smallest value to be found in the literature.


0,00
-0,01
-0,02
-0,03
-0,04
-0,05
-0,06
-0,07
-0,08
0,01
0,1
1
x
x(Δs+Δs̄)
LSS(a8=0.585)
LSS(a8=0.460)
Q2 = 2.5 GeV2

the strange quark polarization from SIDIS

Measured asymmetry in $l + N \to l + h + X$: **In LO**

$$A_1^h(x,z,Q^2) \approx \frac{g_1^h}{F_1^h} = \frac{\sum_{q,\bar{q}} e_q^2\, \Delta q(x,Q^2)\, D_q^h(z,Q^2)}{\sum_{q,\bar{q}} e_q^2\, q(x,Q^2) D_q^h(z,Q^2)}$$

Require (unpolarized) fragmentation function (FF) for $q \to h + X$.

The FFs obtained from multiplicity measurements.

- Using DSS FFs, based on unpublished HERMES data, yields slightly positive $\Delta s(x) + \Delta\bar{s}(x)$!

- But published HERMES data very different. **Therefore should not use original DSS FFs.**

- LSS discovered $\Delta s(x)+\Delta\bar{s}(x)$ very sensitive to FFs.

- As experiment LSS tried HKNS FFs : get negative $\Delta s(x) + \Delta\bar{s}(x)$ [LSS, Phys. Rev. D84 (2011) 014002; slide presented by Stamenov at DIS'2011]

Impact of the HKNS FFs on polarized sea quark densities

- **Negligible changes of $\Delta\bar{d}(x)$ and $\Delta G(x)$ densities**

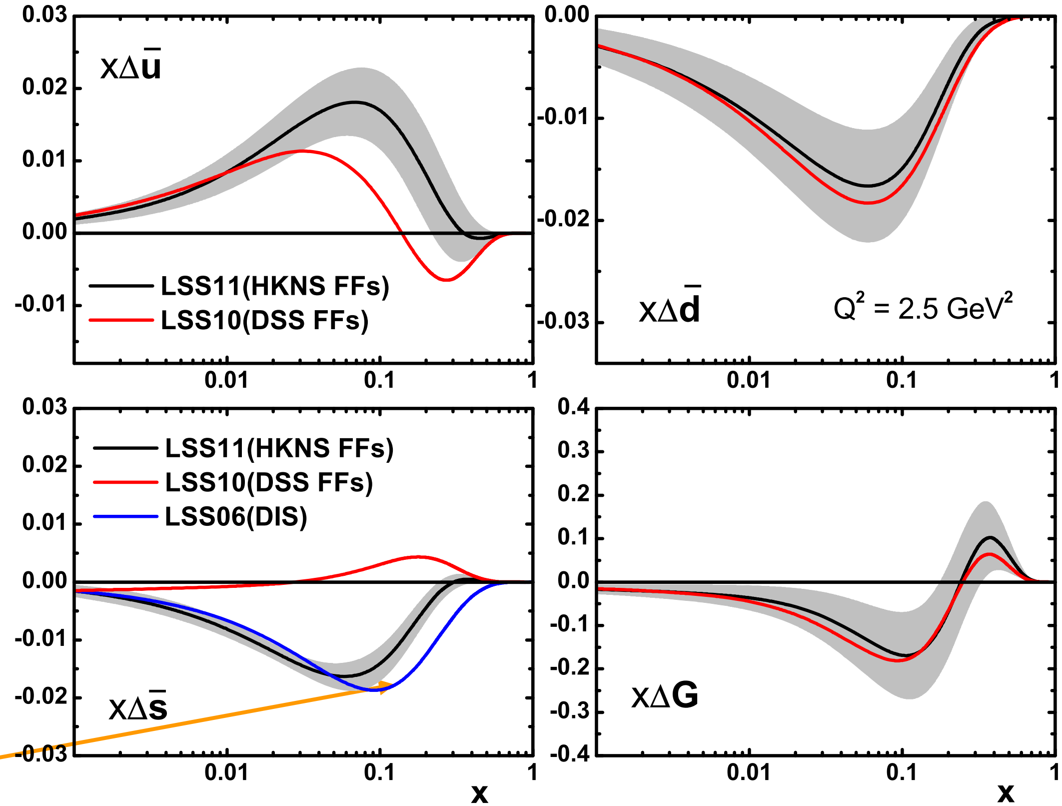
Error bands ⟹ $\Delta\chi^2 = 1$

- **Visible change of $\Delta\bar{u}(x)$ for x > 0.03**

- **Dramatic change of $\Delta\bar{s}(x)$ due to a significant difference in the transition**

$$\bar{s} \rightarrow K^+$$

It is negative for any *x* in the measured region and consistent with $(\Delta s+\Delta\bar{s})(x)/2(DIS)$



$err^2 = stat^2 + sys^2$

KEY MESSAGE: CRUCIAL TO HAVE ACCURATE FFs

THE PROBLEMATIC STATUS OF FRAGMENTATION FUNCTIONS

Two most recent sources of information on FFs:

HERMES: pion and kaon multiplicities

COMPASS: pion multiplicities and just released kaon multiplicities

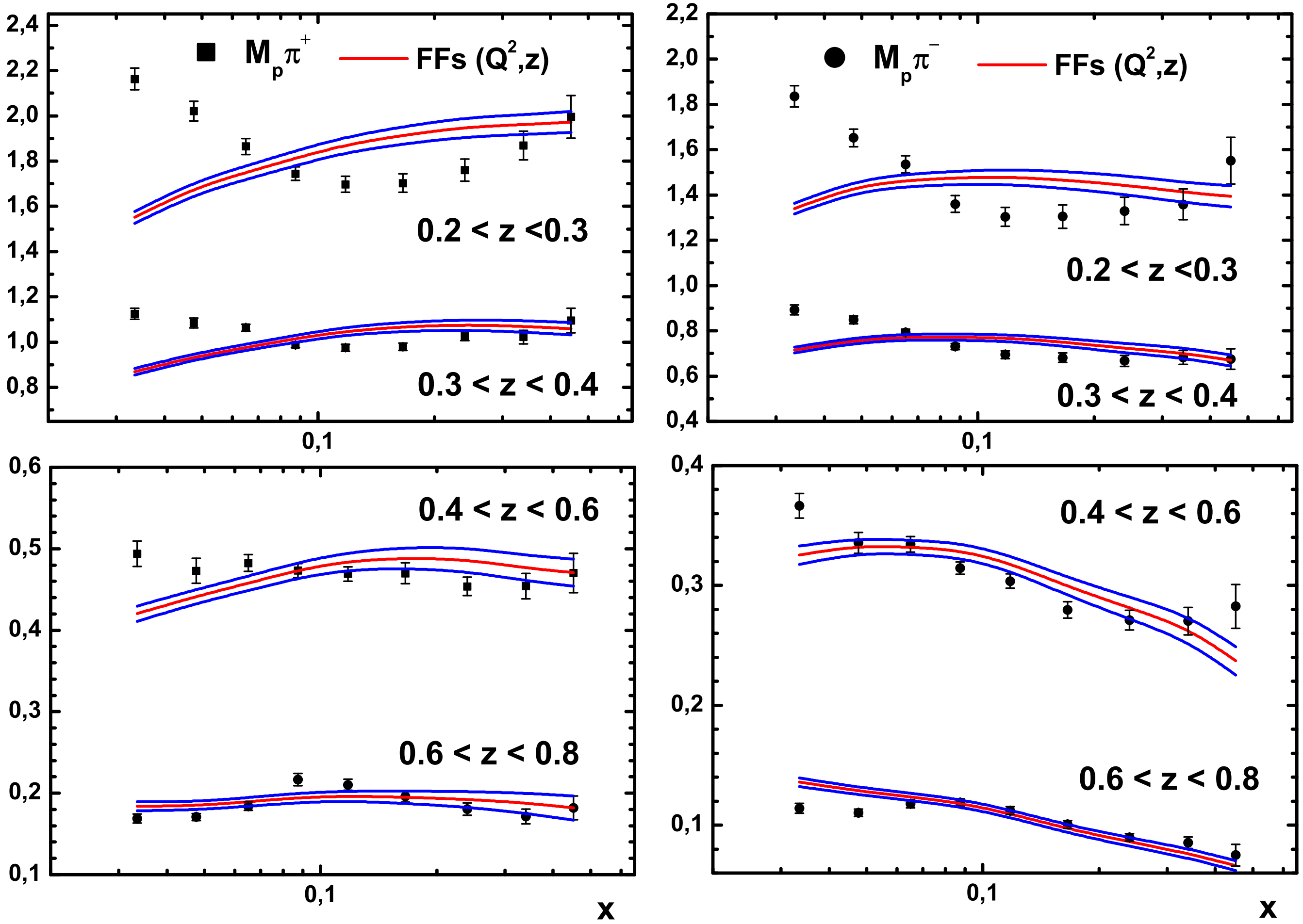
problems with the HERMES data

- For unknown reasons the data in original bins of (x, Q^2, z) were never published

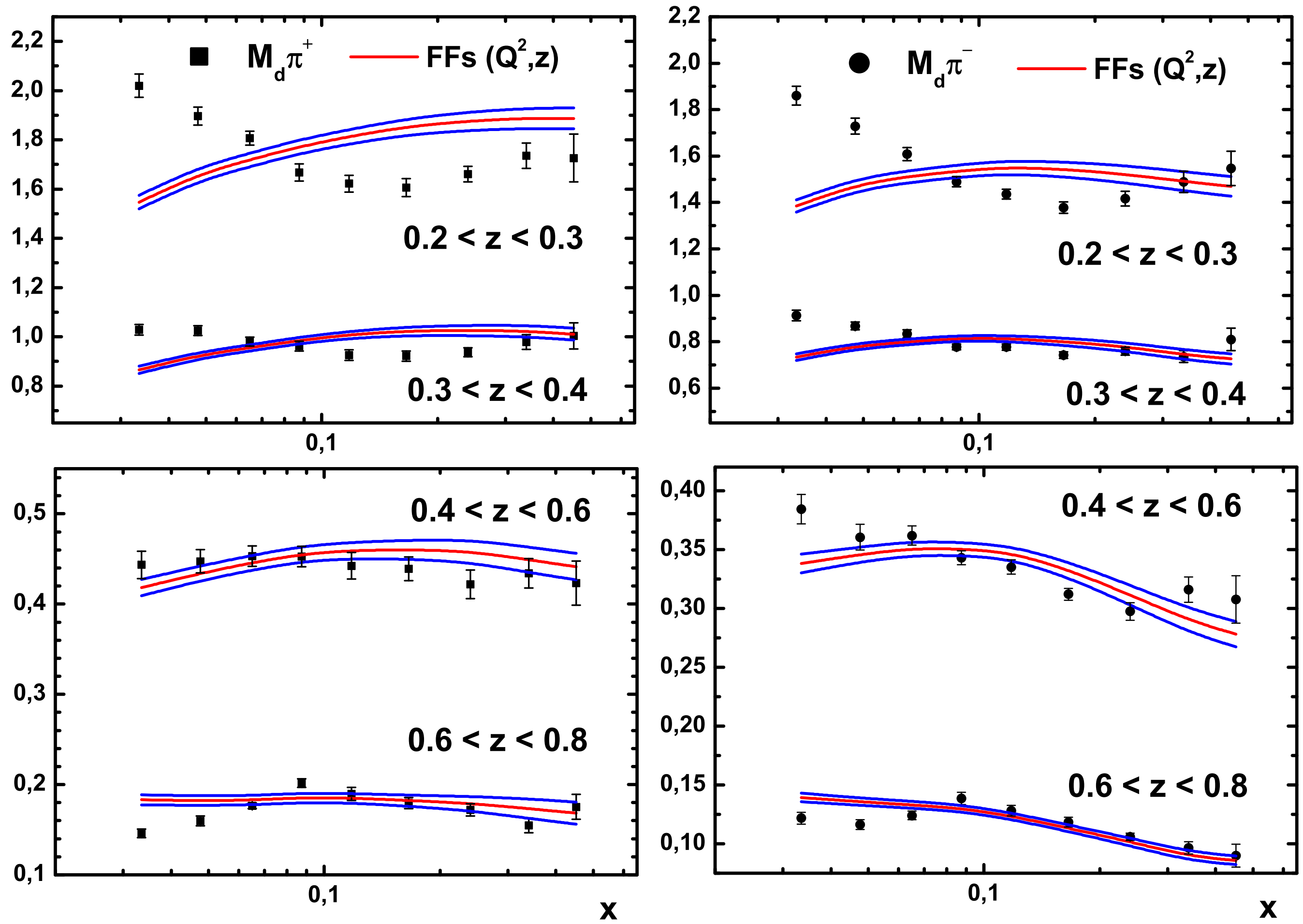
- Two different projections of the data were published: $[Q^2, z]$ and $[x, z]$

- We believe these projections are incompatible

Exercise: extract PION FFs from HERMES $[Q^2, z]$ PION multiplicity data and use them to calculate $[x, z]$ PION multiplicities



$M_p\pi^+$
FFs (Q^2,z)
0.2 < z <0.3
0.3 < z < 0.4
$M_p\pi^-$
FFs (Q^2,z)
0.2 < z <0.3
0.3 < z < 0.4
0.4 < z < 0.6
0.6 < z < 0.8
0.4 < z < 0.6
0.6 < z < 0.8
0,1
x



M_d π⁺
FFs (Q²,z)
0.2 < z < 0.3
0.3 < z < 0.4
M_d π⁻
FFs (Q²,z)
0.2 < z < 0.3
0.3 < z < 0.4
0.4 < z < 0.6
0.6 < z < 0.8
0.4 < z < 0.6
0.6 < z < 0.8
0,1
x

Exercise: extract PION FFs from HERMES $[x, z]$
PION multiplicity data: χ^2 terrible

- Hence: base extraction on the HERMES $[Q^2, z]$ PION multiplicity data only: [LSS'15 PION FFs]

- Revised DSS i.e. DSEHS'15 PION FFs, global, but also based on HERMES $[Q^2, z]$

Further problems: HERMES vs COMPASS pion multiplicities

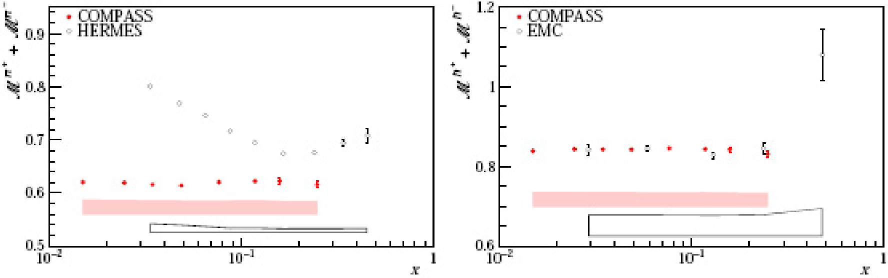


Figure 7: Left: Sum of $\mathcal{M}^{\pi^+}$ and $\mathcal{M}^{\pi^-}$ versus x. The COMPASS data (closed circles) are compared to HERMES results (open circles); Right: Sum of $\mathcal{M}^{h^+}$ and $\mathcal{M}^{h^-}$ versus x. The COMPASS data (closed circles) are compared to EMC results (open circles). The systematic uncertainties are shown as bands at the bottom.

Further problems: HERMES vs COMPASS kaon multiplicities

COMPASS has just released its data on Kaon multiplicities——
——-again significantly different from HERMES

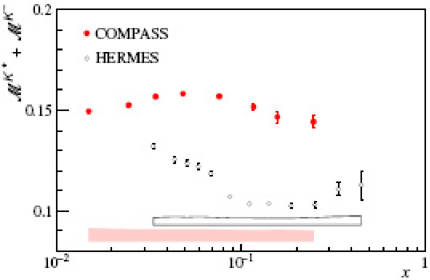


Figure 8: Sum of z-integrated multiplicities, $\mathcal{M}^{K^+} + \mathcal{M}^{K^-}$. COMPASS data (full points) are compared to HERMES data [11] (open points). The bands show the total systematic uncertainties.

Conclusions

1. The positive values of $\Delta s(x)+\Delta\bar{s}(x)$ obtained from the SIDIS analysis using DSS FFs, in contrast to the negative values obtained in **ALL** DIS studies, is certainly due to the DSS KAON FFs being incorrect.

2. It is clear that $\Delta s(x) + \Delta\bar{s}(x)$ is very sensitive to the KAON FFs.

3. The HKNS FFs yield negative values for $\Delta s(x) + \Delta\bar{s}(x)$, compatible with the DIS results, but the HKNS FFs are not compatible with HERMES and COMPASS mutiplicities.

4. There is confusion about the PION FFs. There appears to be an inconsistency between the two projections of the HERMES SIDIS pion data.

5. There is significant disagreement between the HERMES and COMPASS pion and kaon multiplicities.

6. It looks as if KAON FFs based on the COMPASS data will yield negative strange quark polarization.

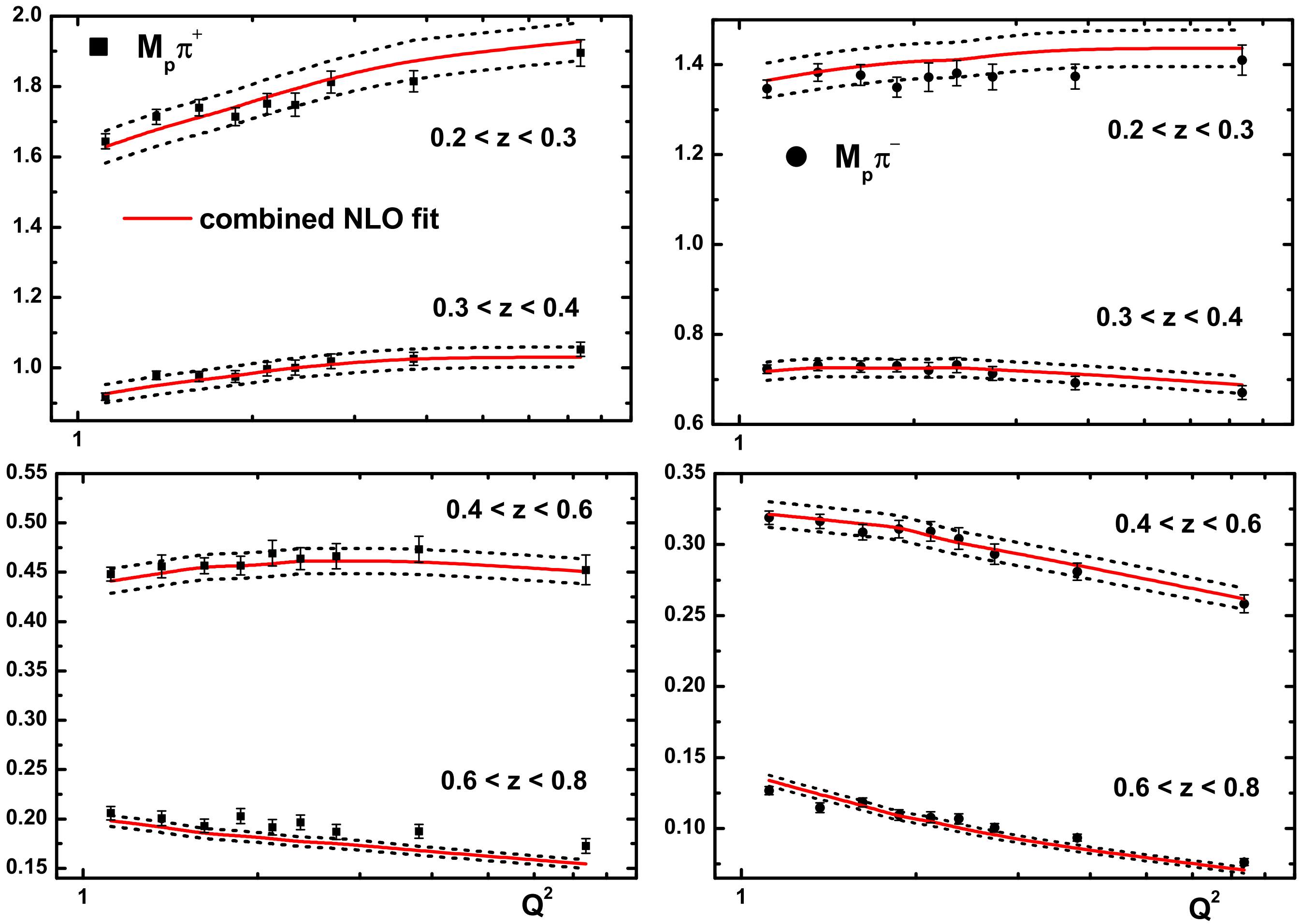
Extra Slides

STOP PRESS

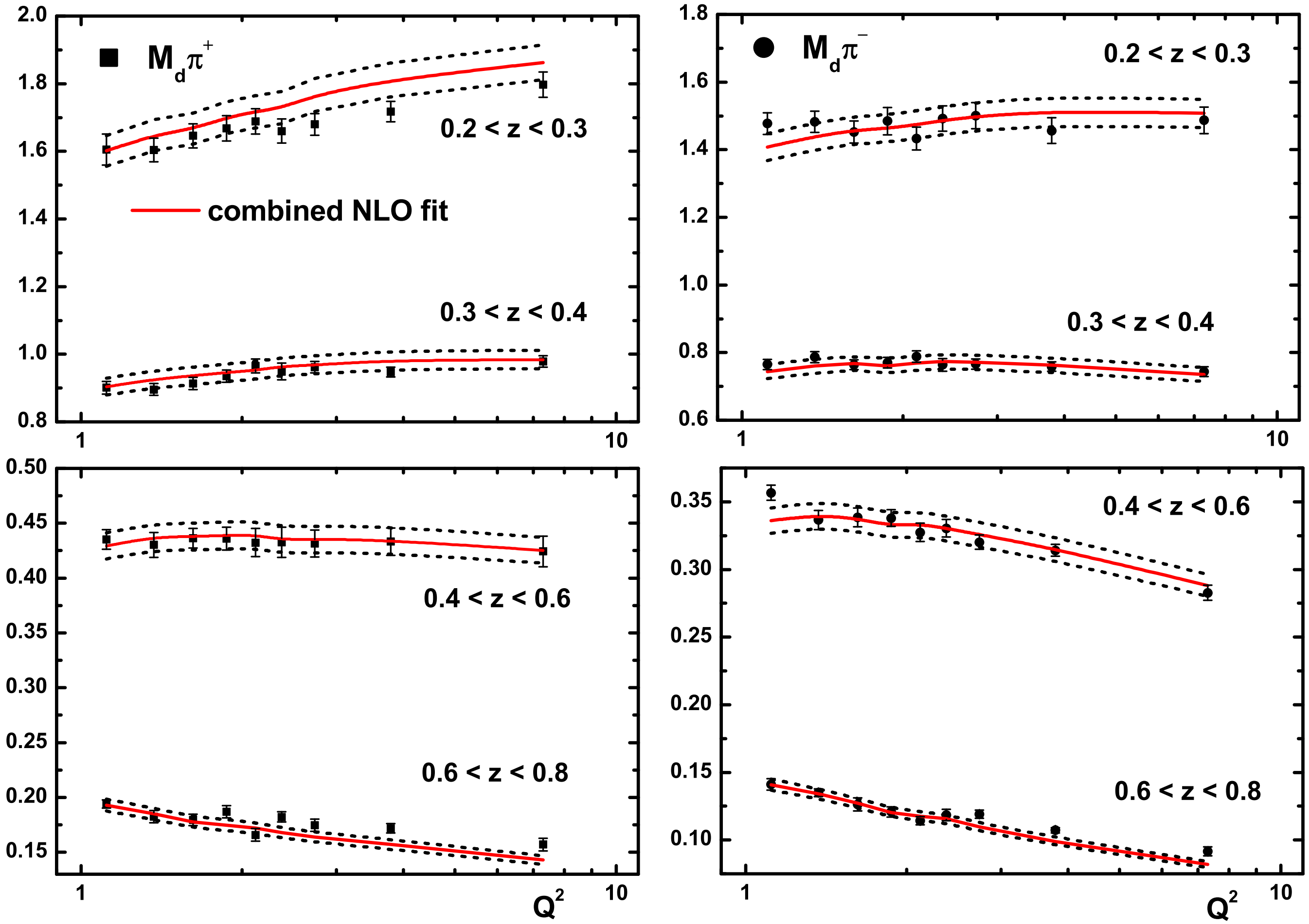
Preliminary new LSS results

HERMES $[Q^2, z]$ and COMPASS $[x, y, z]$

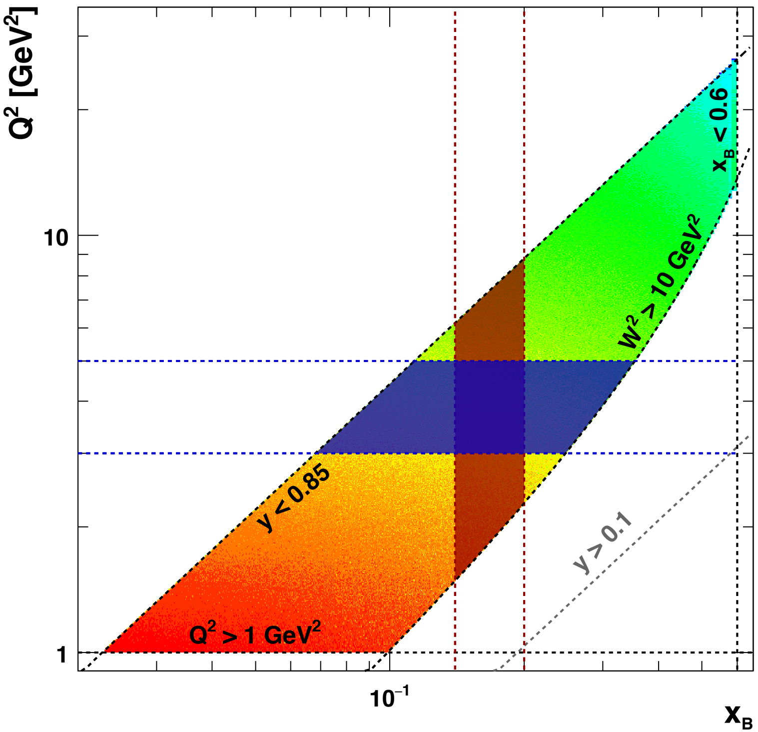
pion data ARE largely COMPATIBLE



M_p π^+
combined NLO fit
0.2 < z < 0.3
0.3 < z < 0.4
M_p π^-
0.2 < z < 0.3
0.3 < z < 0.4
0.4 < z < 0.6
0.6 < z < 0.8
0.4 < z < 0.6
0.6 < z < 0.8
Q^2
Q^2



$M_d \pi^+$
combined NLO fit
0.2 < z < 0.3
0.3 < z < 0.4
0.4 < z < 0.6
0.6 < z < 0.8
$M_d \pi^-$
0.2 < z < 0.3
0.3 < z < 0.4
0.4 < z < 0.6
0.6 < z < 0.8
Q^2
Q^2



Q² [GeV²]
10
1
10⁻¹
x_B
x_B < 0.6
W² > 10 GeV²
y < 0.85
y > 0.1
Q² > 1 GeV²