PRESENT STATUS OF POLARIZED PARTON DENSITIES ... AND FRAGMENTATION FUNCTIONS.

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A) GENERALITIES

B) FLAVOUR SEPARATION

C) MOST RECENT DETERMINATIONS OF POLARIZED DENSITIES.

D) COMPARISON OF RESULTS

E) THE RÔLE OF 3F−D

F) CONCLUSIONS ON POLARIZED DIS :

$\Delta u + \Delta\bar{u}$, $\Delta d + \Delta\bar{d}$, $\Delta\Sigma$ well determined

$\left.\begin{array}{l} \Delta s + \Delta\bar{s} \quad \text{reasonable} \\ \Delta G \quad \text{fair, with } \int \Delta G\, dx > 0 \end{array}\right\}$ with $a_8 = 3F - D$

→ POOR IF DON'T TRUST $a_8 = 3F - D$

G) THE NEAR FUTURE : SIDIS

FRAGMENTATION FUNCTIONS FOR PIONS DETERMINED.

SURPRISE : $D_d^{\pi^+}$ NOT NEGLIGIBLE.

Analysis Papers Referred To: —

AAC (2000) : Asymm. Analysis Collab.
(Goto et al. P.R. D62, 034017)

GRSV (2001) : Glück, Reya, Stratmann, Vogelsang
(P.R. D63, 094005)

LSS (2001) : Leader, Sidorov, Stamenov
(HEP-PH/0111267 : Eur. Phys. J. C (2002))

SMC (1998) : Adeva et al
(P.R. D58, 112002)

A) GENERALITIES

1) Connection between THEORY AND EXPT.

a) $A_1 \approx (1+\gamma^2)\; g_1/F_1$

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

$\gamma^2 = 4m^2x^2/Q^2$: Can be 10-20% for

E143, E155, HERMES.

$\therefore$ Keep $(1+\gamma^2)$ if use F_1.

b) Higher Twist (HT) : Since forced to use data at small Q^2,

$$F_{1,2_{EXP}} = F_{1,2}^{QCD} + F_{1,2}^{HT}$$

$$R_{EXP} = R^{QCD} + R^{HT}$$

$$g_{1_{EXP}} = g_1^{QCD} + g_1^{HT}$$

Two approaches :

SMC (98), AAC (2001) : Fit

$$g_1^{QCD} = \left[\frac{F_2}{2x(1+R)}\right]_{EXP} \cdot A_{1_{EXP}} \qquad HT\ ?$$

GRSV (2001), LSS (2001) : Fit

$$g_1^{QCD} = (1+\gamma^2)^{-1} F_1^{QCD} A_{1\,EXP}$$

Reason: Both show that if put

$$A_{1\,EXP} = (1+\gamma^2)\, g_1^{QCD} / F_1^{QCD} + A_1^{HT}$$

FIND $A_1^{HT} \approx 0$ (Fig)

For unknown reason seems that HT in F_1 and g_1 approx. cancel.

2) FACTORIZATION SCHEME DEPENDENCE.

IN PRINCIPLE $g_{1\,\overline{MS}} = g_{1\,AB} = g_{1\,JET}$

(JET is THE CHIRAL INVARIANT SCHEME)

BUT TO FINITE ORDER IN PERT. THEORY

$$g_{1\,\overline{MS}} \neq g_{1\,AB} \neq g_{1\,JET}$$

CONSEQUENCE: ONE SCHEME MAY BE BETTER THAN ANOTHER

$$A_1^{EXPT} = A_{1\,LSS(2001)}^{QCD} + \frac{h(x)}{Q^2}$$

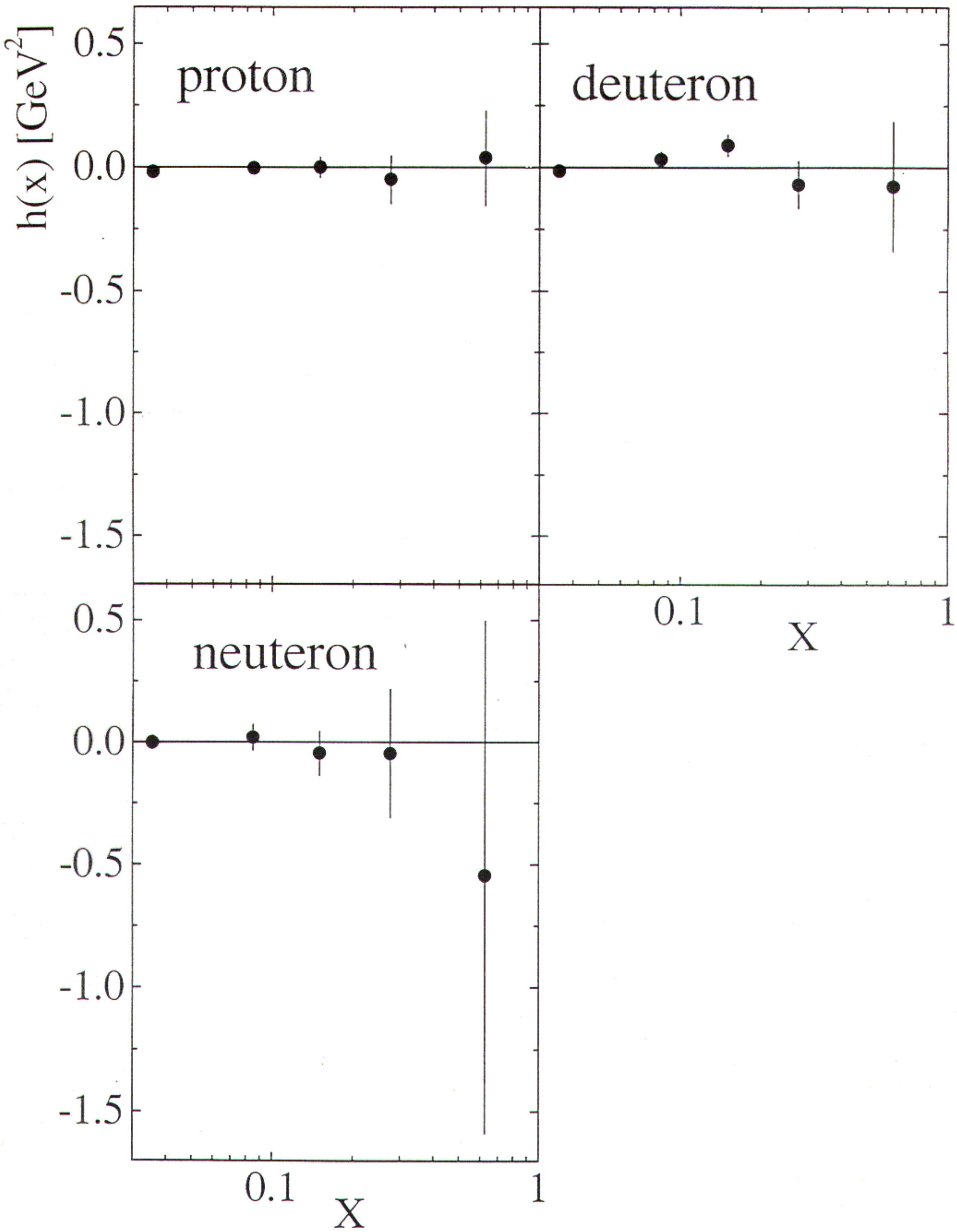


Fig. 1

ON THEORETICAL GROUNDS LSS prefers JET.

$\therefore$ GOOD TO DO ANALYSIS IN VARIOUS SCHEMES.

THEY ARE RELATED BY SIMPLE FORMULAE :

A USEFUL CHECK : DO RESULTS OF FITTING PROCESS SATISFY THESE RELATIONS ?

e.g. SHOULD HAVE :

$$\Delta G(x)_{\overline{MS}} \simeq \Delta G(x)_{AB} \simeq \Delta G(x)_{JET}$$

FAILS BADLY IN SOME ANALYSES. IF A GENUINE EFFECT $\Longrightarrow$ $\boxed{\text{NNLO}}$ IMPORTANT !

N.B. $\int dx\, \Delta\Sigma_{AB}(x, Q^2)$, $\int dx\, \Delta\Sigma_{JET}(x, Q^2)$

are INDEP of Q^2. More meaningful for comparison with low Q^2 static quark model.

B) FLAVOUR SEPARATION

THIS IS THE REAL CHALLENGE

FOR THE FUTURE !

$$6\left[g_1^p(x,Q^2) - g_1^n(x,Q^2)\right] = \delta C_{NS} \otimes \Delta q_3(x,Q^2)$$

$$\frac{9}{2}\left[g_1^p(x,Q^2) + g_1^n(x,Q^2)\right] = \frac{1}{4}\delta C_{NS} \otimes \Delta q_8(x,Q^2) +$$

$$+ \delta C_S \otimes \Delta\Sigma(x,Q^2) + \delta C_G \otimes \Delta G(x,Q^2)$$

PROBLEMS :

1) Separation of Δq_8 from $\Delta\Sigma, \Delta G$ depends ENTIRELY ON EVOLUTION.

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

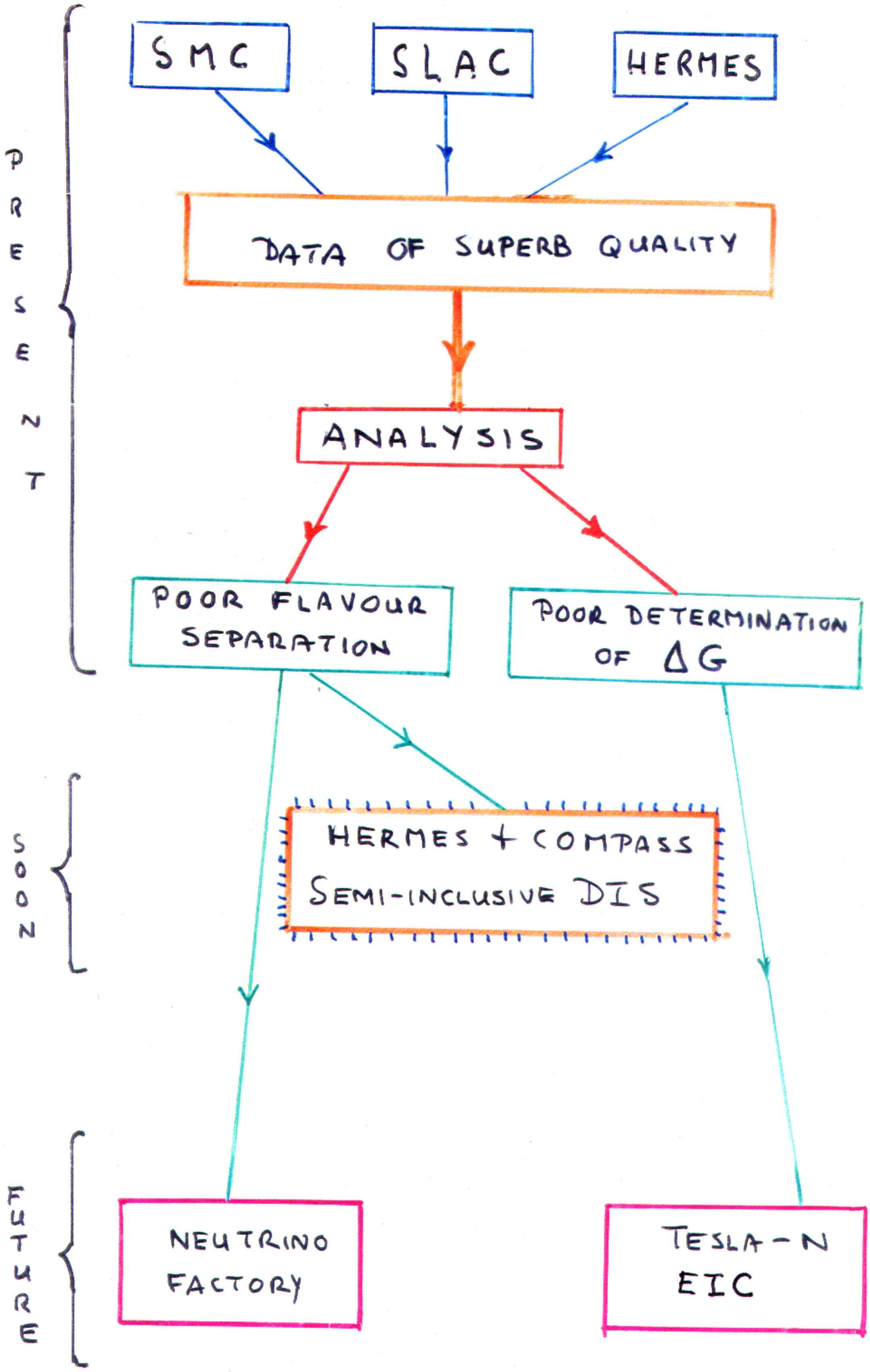
$\Delta q_8 = (\Delta u + \Delta\bar{u}) + (\Delta d + \Delta\bar{d}) - 2(\Delta s + \Delta\bar{s})$

$\Delta\Sigma = (\Delta u + \Delta\bar{u}) + (\Delta d + \Delta\bar{d}) + (\Delta s + \Delta\bar{s})$

$\therefore$ MANIFESTLY : NO INFORMATION ABOUT VALENCE / SEA

PRESENT SITUATION ----.

STATUS OF POLARIZED DIS : $\Delta q(x)$



c) MOST RECENT DETERMINATIONS OF POLARIZED DENSITIES.

1) WHAT should we parametrize ?

Physical intuition $\Rightarrow \Delta q_V , \Delta \bar{q}$

Simpler to use $\Delta q_3 , \Delta q_8$ or

$\Delta q^p_{NS} , \Delta q^n_{NS}$ BUT DANGEROUS !

(SMC $\Delta \bar{q}$)

2) Need $\Delta q_V, \Delta \bar{q}$ for OTHER REACTIONS

BUT DIS DOES NOT determine them.

Free to model the sea

e.g. SU(3) symm: $\Delta \bar{u} = \Delta \bar{d} = \Delta \bar{s}$

or BROKEN SU(3): $\Delta \bar{u} = \Delta \bar{d} = \lambda \Delta \bar{s}$ etc.

FINE ! BUT DON'T CLAIM TO HAVE DETERMINED $\Delta \bar{q}$!

AND CHECK THAT MODEL DOES NOT BIAS FIT TO DATA ! .... AND ...

SMC (98): Nice smooth parametrization of Δq^p_{NS} and Δq^n_{NS} $\Longrightarrow$

UNPHYSICAL $\Delta \bar{q}$

FROM:

Y. GOTO *et al.* AAC (2000)

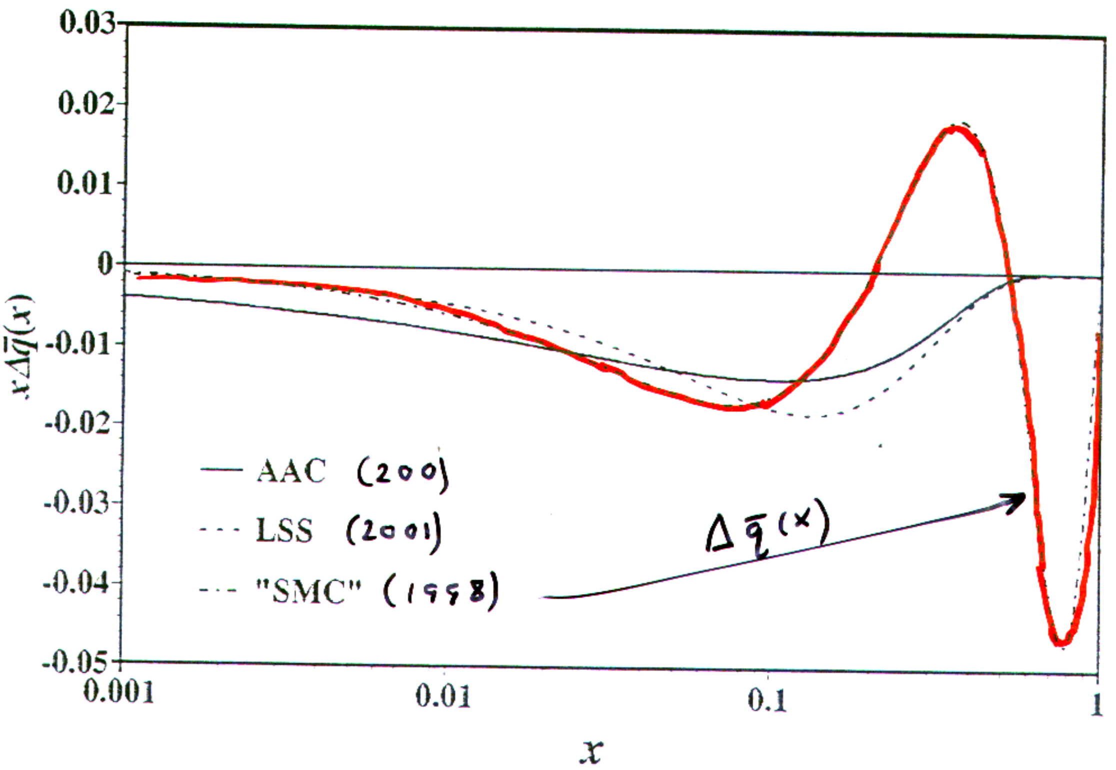


FIG. 8. The antiquark distributions of transformed SMC ("SMC") and LSS(1999) are compared with our NLO-1 distribution at $Q^2=1$ GeV^2. ($\overline{MS}$)

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AND PRESENT RESULTS FOR

Δu_v, Δd_v, $\Delta \bar{q}$, ΔG

AND FOR

$\Delta u + \Delta \bar{u}$, $\Delta d + \Delta \bar{d}$, $\Delta s + \Delta \bar{s}$, ΔG

3) What about sum rules?

At present better to impose

Bjorken Sum Rule, and

$$a_8 \equiv \int \Delta q_8 (x, Q^2) dx = 3F - D$$

from: HYPERON β-DECAY ASSUMING SU(3)

BUT: MANY PAPERS QUESTION USE OF EXACT SU(3) IN HYPERON DECAY

$\Longrightarrow$ IN DIS SHOULD STUDY SENSITIVITY OF PARTON DENSITIES TO value for a_8.

D) RESULTS.

AAC (2000), GRSV (2001), LSS (2001).

Common features:

1) $\Delta f = h(x)\, f(x)$ at Q_0^2

2) $a_3 = g_A = F+D$ $\quad a_8 = 3F-D$ used

	AAC	(STANDARD) GRSV	LSS
$f(x)$	GRS (98) $Q_0^2 = 1$	GRS (98) $Q_0^2 = 0.4$	MRST (99) $Q_0^2 = 1$
$h(x)$	$x^\alpha (1+\gamma x^\lambda)$	$x^\alpha (1-x)^\beta$	x^α
g_A	1.267 ± 0.011	1.2670 ± 0.0035	1.2670 ± 0.0035
$3F-D$	0.585 ± 0.025	0.58 ± 0.15	0.585 ± 0.025
DATA	NOT E155	ALL	ALL
Number of parameters	14	12	6

3) All use SU(3) symm. sea

(GRSV also looks at "valence scenario")

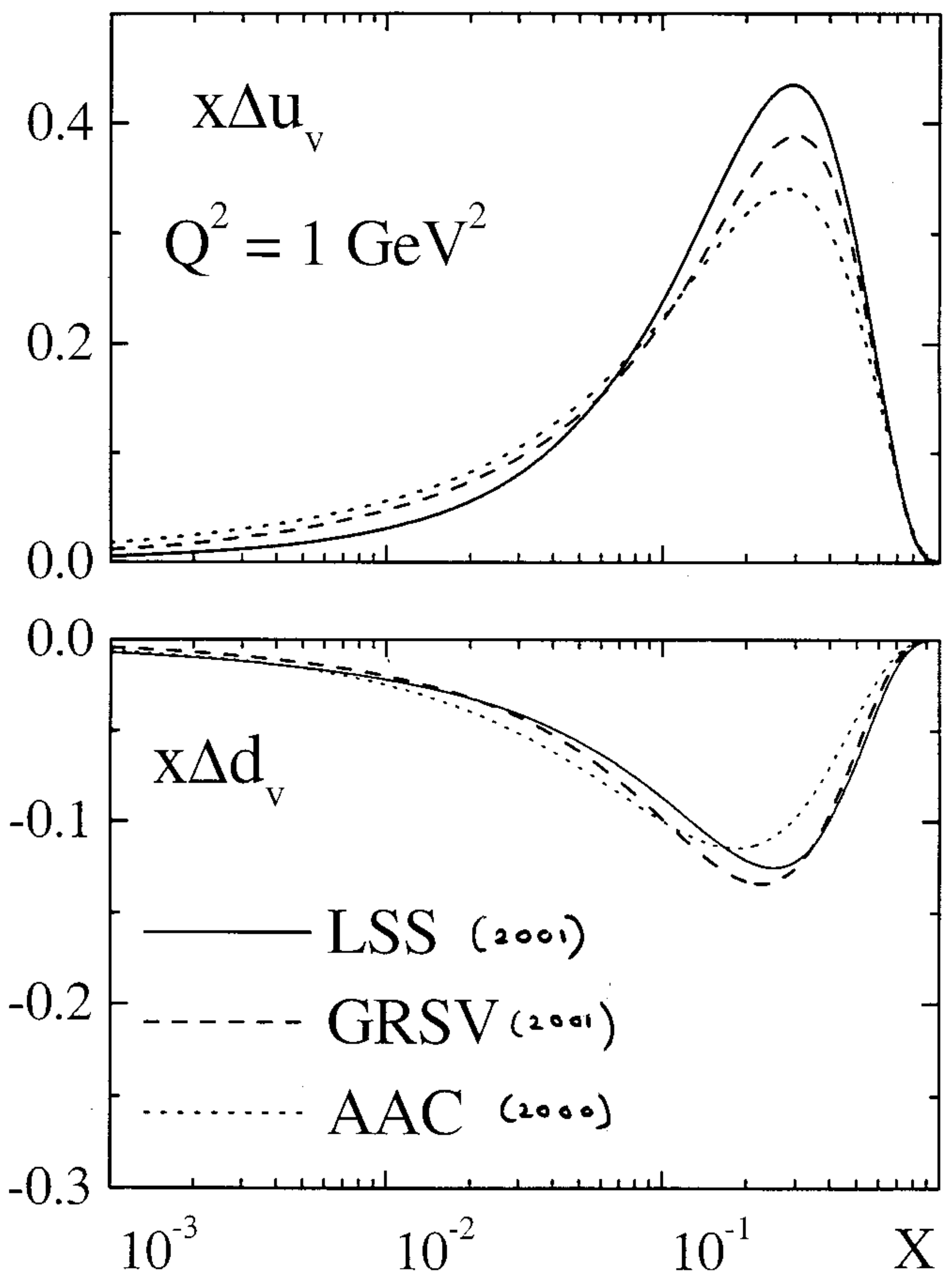
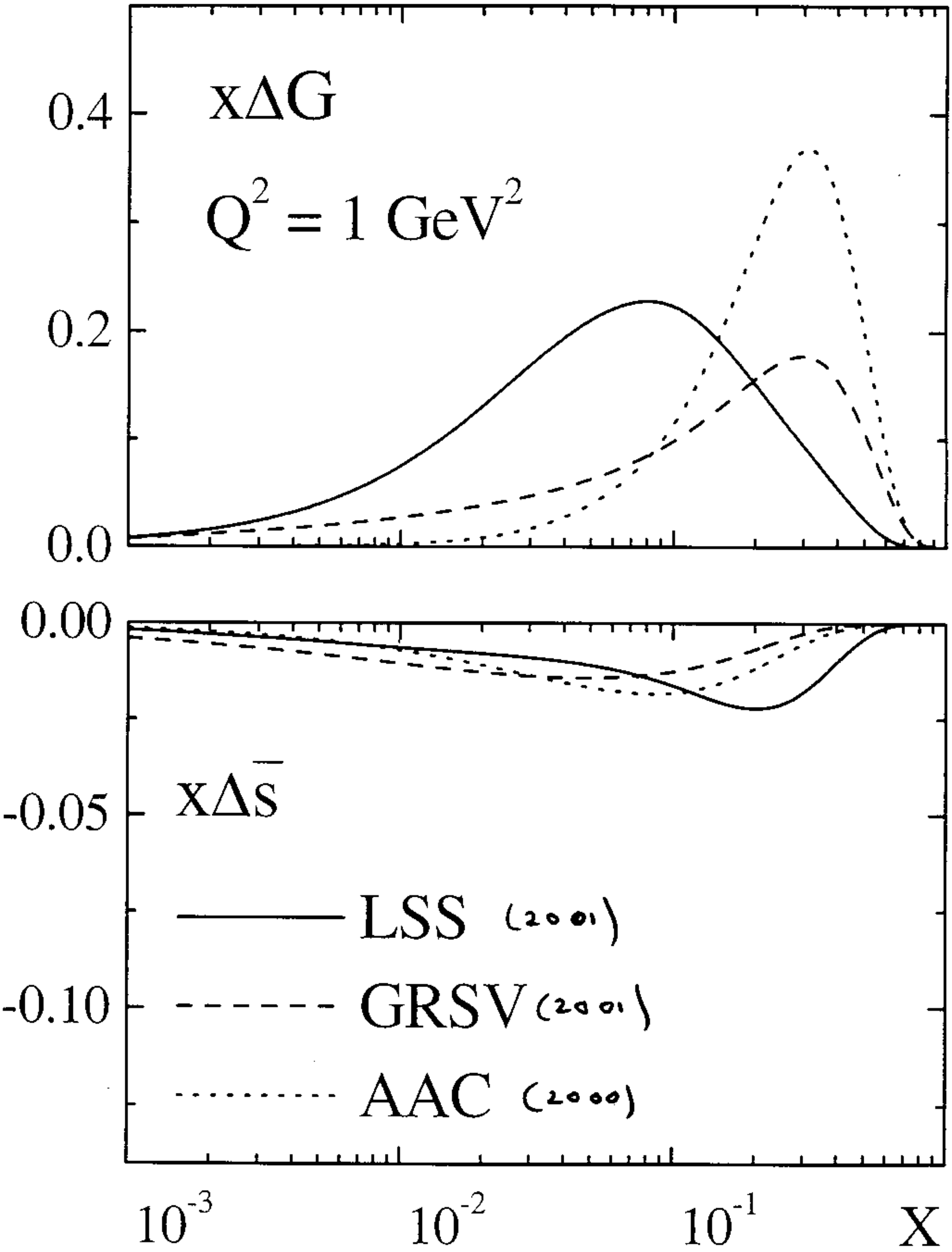

xΔu_v
Q^2 = 1 GeV^2
0.4
0.2
0.0
xΔd_v
0.0
-0.1
-0.2
-0.3
LSS (2001)
GRSV (2001)
AAC (2000)
10^-3
10^-2
10^-1
X

Fig. 8 (a)



xΔG
Q² = 1 GeV²
0.4
0.2
0.0
0.00
xΔs̄
-0.05
-0.10
LSS (2001)
GRSV (2001)
AAC (2000)
10⁻³
10⁻²
10⁻¹
X

Fig. 8(b)

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(FIRST MOMENTS ARE AT $Q^2 = 1$)

	AAC	GRSV	LSS
SCHEME USED IN FIT	$\overline{MS}$	$\overline{MS}$	JET
$\Delta\Sigma_{\overline{MS}}$	$\left\{\begin{array}{l}0.051\\ \alpha_{\bar q}\ \text{FREE}\end{array}\right.$ $\left\{\begin{array}{l}0.241\\ \alpha_{\bar q} = 1\end{array}\right.$	0.204	0.21 BY TRANS.
$\Delta\Sigma_{JET}$			0.37 $\pm$ 0.07
$\Delta G_{\overline{MS}}$	0.532	0.420	0.68
ΔG_{JET}			0.68 $\pm$ 0.32
$(\Delta s + \Delta\bar{s})_{\overline{MS}}$	−0.178 −0.114	−0.126	−0.13
$(\Delta s + \Delta\bar{s})_{JET}$			−0.07 $\pm$ 0.02

$$\alpha_{\bar q}^{FREE} = 0.32 \pm 0.22$$

E) THE RÔLE OF 3F − D

How sensitive are PDs to the value of $a_8 \equiv \int \Delta q_8(x, Q^2)\, dx$

$= 3F - D$ usually ?

STUDIED IN LSS : Phys. Lett. B 488, 283

Take $a_8 = 0.40$

0.58 $(= 3F - D)$

0.86

Find: $\Delta u + \Delta \bar{u}$, $\Delta d + \Delta \bar{d}$ STABLE

$\Delta s + \Delta \bar{s}$, ΔG LARGE CHANGES

$\Delta \Sigma$ FAIRLY STABLE

(Figs)

These are extreme values in literature, maybe much too pessimistic!

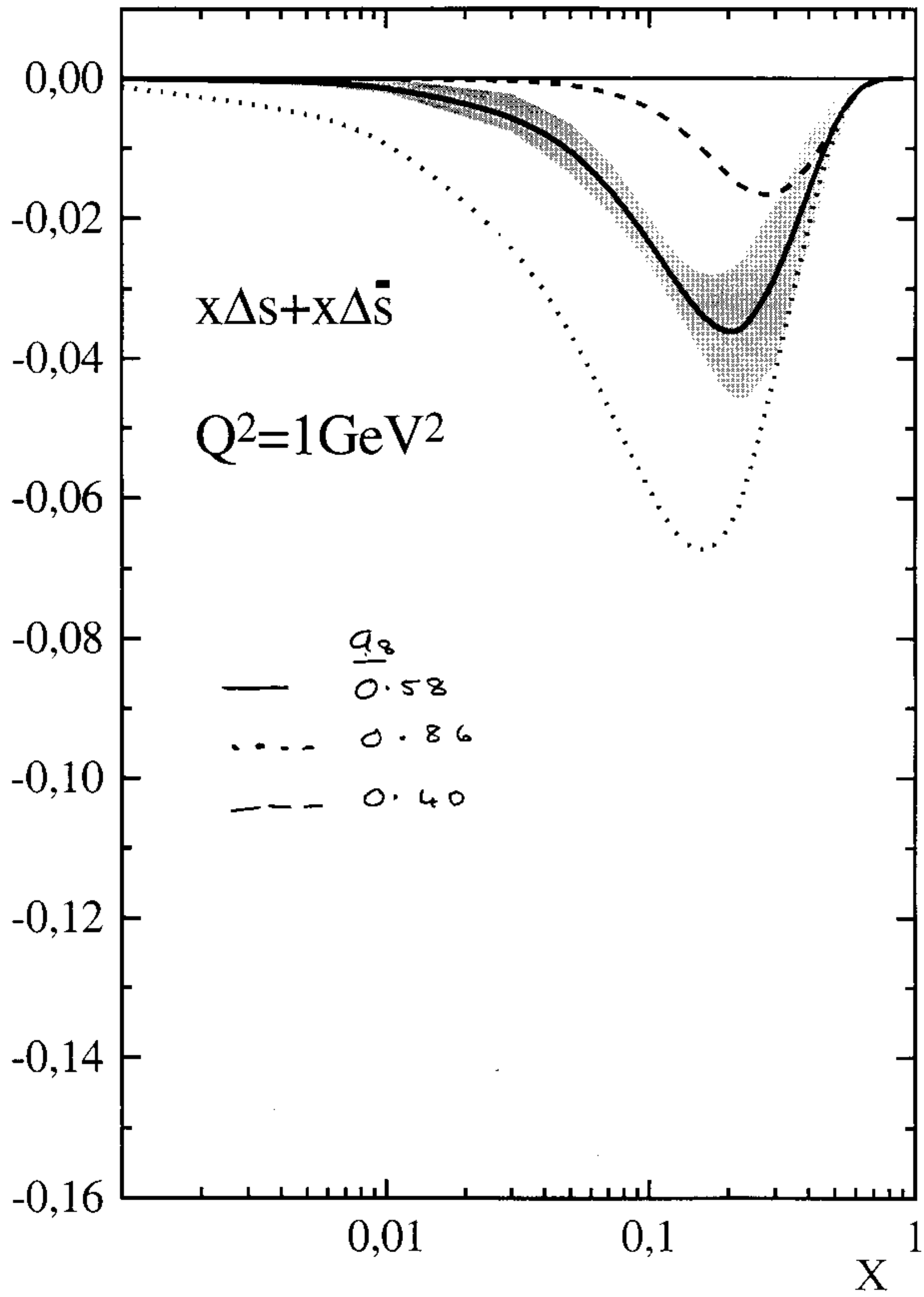
0,00
-0,02
-0,04
-0,06
-0,08
-0,10
-0,12
-0,14
-0,16
0,01
0,1
1
X
xΔs+xΔs̄
Q2=1GeV2
q8
0.58
0.86
0.40

Fig. 3

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2.3

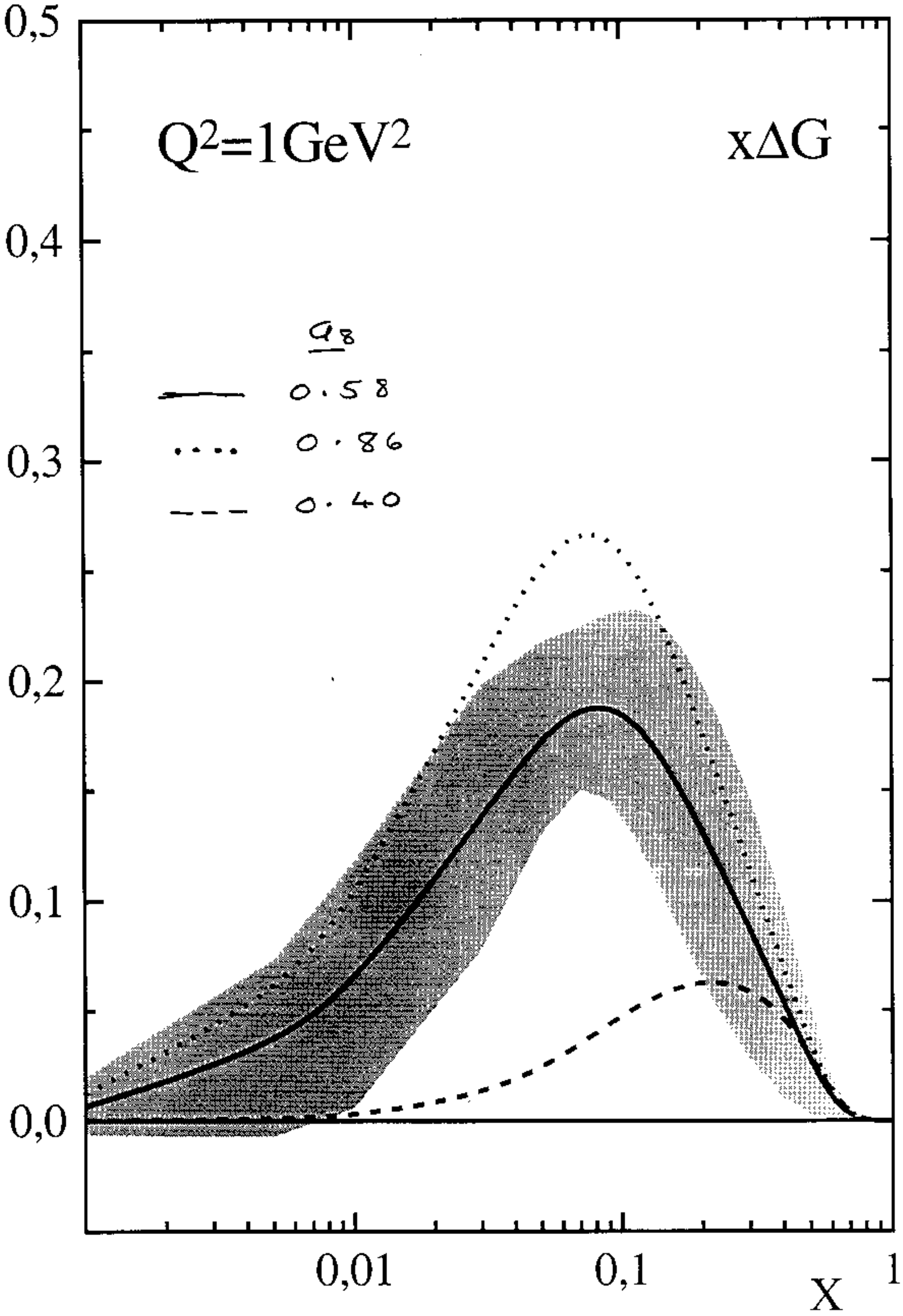

Fig. 5

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F) CONCLUSIONS.

1) SUPERB DIS DATA YIELD WELL DETERMINED $\Delta u + \Delta \bar{u}$, $\Delta d + \Delta \bar{d}$

2) If accept $a_8 = 3F - D$ then

$\Delta s + \Delta \bar{s}$ reasonably well determined

ΔG not well constrained, but

$$\int dx \, \Delta G(x) > 0 \quad \text{at } Q^2 = 1$$

3) If give up $a_8 = 3F - D$ then

$\Delta s + \Delta \bar{s}$ and ΔG poorly determined,

and $\int dx \, \Delta G(x) = 0$ is possible.

4) VITALLY IMPORTANT TO HAVE GOOD SIDIS DATA SOON !

G) THE NEAR FUTURE

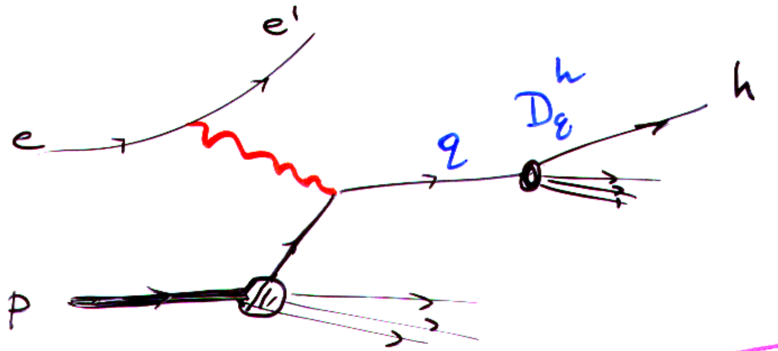
SEMI - INCLUSIVE DIS

$$\ell p \to \ell' h X$$

(COMPASS, HERMES)

ONLY REALISTC PROSPECT FOR FLAVOUR AND SEA SEPARATION IN POLARIZED CASE IS FROM SEMI-INCLUSIVE DIS :

$$\vec{e} + \vec{p} \longrightarrow e' + h + X$$



$u(x)$
$D_u^h(z)$

$$\tilde{\sigma}^h = \frac{4}{9}\left[u D_u^h + \bar{u} D_{\bar{u}}^h\right] + \frac{1}{9}\left[d D_d^h + \bar{d} D_{\bar{d}}^h + s D_s^h + \bar{s} D_{\bar{s}}^h\right]$$

$$\Delta\tilde{\sigma}^h = \frac{4}{9}\left[\Delta u D_u^h + \Delta\bar{u} D_{\bar{u}}^h\right] + \frac{1}{9}\left[\Delta d D_d^h + \Delta\bar{d} D_{\bar{d}}^h + \Delta s D_s^h + \Delta\bar{s} D_{\bar{s}}^h\right]$$

NB : SAME FFs in $\tilde{\sigma}$ AND $\Delta\tilde{\sigma}$

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∴ NEED FFs !!! (TO STUDY $\Delta q(x)$)
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How well do we know the Fragmentation Functions (FFs) ?

Until recently: Binneweis et al : $e^+e^- \to h X$

2000/2001 : $e^+e^- \to h X$: more data, improved treatment, by 3 groups:

KRETZER
KNIEHL et al
BOURHIS et al

FFs for individual flavours disagree, badly in some cases !

e^+e^- has poor flavour discrimination.

SIDIS with PIONS :

CHARGE CONJUGATION INVARIACE
ISOSPIN INVARIANCE } ⇒

ONLY 3 INDEPENDENT FFs :

$$D_u^{\pi^+}, \quad \underbrace{D_d^{\pi^+}, \quad D_s^{\pi^+}}_{\text{OFTEN ASSUMED NEGLIGIBLE}}$$

HERMES HAS DATA ON $\pi^{\pm}$

PRODUCTION ON PROTONS (UNPOLD)

$\therefore$ 2 pieces of information

1 more needed

THE TRICK : CONSIDER $e^+e^- \to \pi X$

AT LOW Q^2 COUPLING IS E.M.

$$e_u^2 > e_d^2$$

AT Z^0 COUPLING IS ELECTROWEAK

$$e_u^{EW} < e_d^{EW}$$

$\Longrightarrow \exists$ a MAGIC energy where

the overall couplings are equal. (Fig)

$$\sigma_{MAGIC}^{e^+e^-\to\pi X} \propto \tilde{e}^2 \Big\{ \underbrace{D_u^{\pi^+} + D_d^{\pi^+} + D_s^{\pi^+} \cdots}_{} \Big\}$$

$D_\Sigma^{\pi^+} \equiv$ FLAVOUR SINGLET

COMBINATION OF FFs.

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Can show that, at Z^0,

$$\frac{D_\Sigma^{\pi^+}}{\frac{43}{77}\left(D_{\text{MEASURED}}^{\pi^+ + \pi^-} / e_d^2\right)} = 1.00 \pm 0.02 \quad !$$

CONCLUSION: We know $D_\Sigma^{\pi^+}$ QUITE ACCURATELY AT $Q^2 = M_Z^2$

EVOLUTION DOWN TO Q^2_{HERMES} INVOLVES MIXING WITH D_G^{π} (poorly known)

RESULT: Believe we know $D_\Sigma^{\pi^+}$ AT Q^2_{HERMES} TO $\pm 10\%$

$$D_u^{\pi^+} - D_d^{\pi^+} = \frac{9\left(R^{\pi^+} - R^{\pi^-}\right)}{4u_v - d_v}\,\tilde{\sigma}^{DIS}$$

$$D_u^{\pi^+} + D_d^{\pi^+} = \frac{9\left(R^{\pi^+} + R^{\pi^-}\right)\tilde{\sigma}^{DIS} - 2sD_\Sigma^{\pi^+}}{4\left(u + \bar{u} - s\right) + d + \bar{d}}$$

$$D_s^{\pi^+} = \frac{-18\left(R^{\pi^+} + R^{\pi^-}\right)\tilde{\sigma}^{DIS} + \left[4(u+\bar{u}) + d + \bar{d}\right] D_\Sigma^{\pi^+}}{2\left[4\left(u + \bar{u} - s\right) + d + \bar{d}\right]}$$

NOTE :

1) $D_u - D_d$ IS INDEPENDENT OF D_Σ

2) $D_u + D_d$ DEPENDS WEAKLY ON D_Σ

3) D_s IS MOST SENSITIVE TO D_Σ

(Figs)

$$\left(R^h = \frac{\sigma^h}{\sigma_{DIS}} \right)$$

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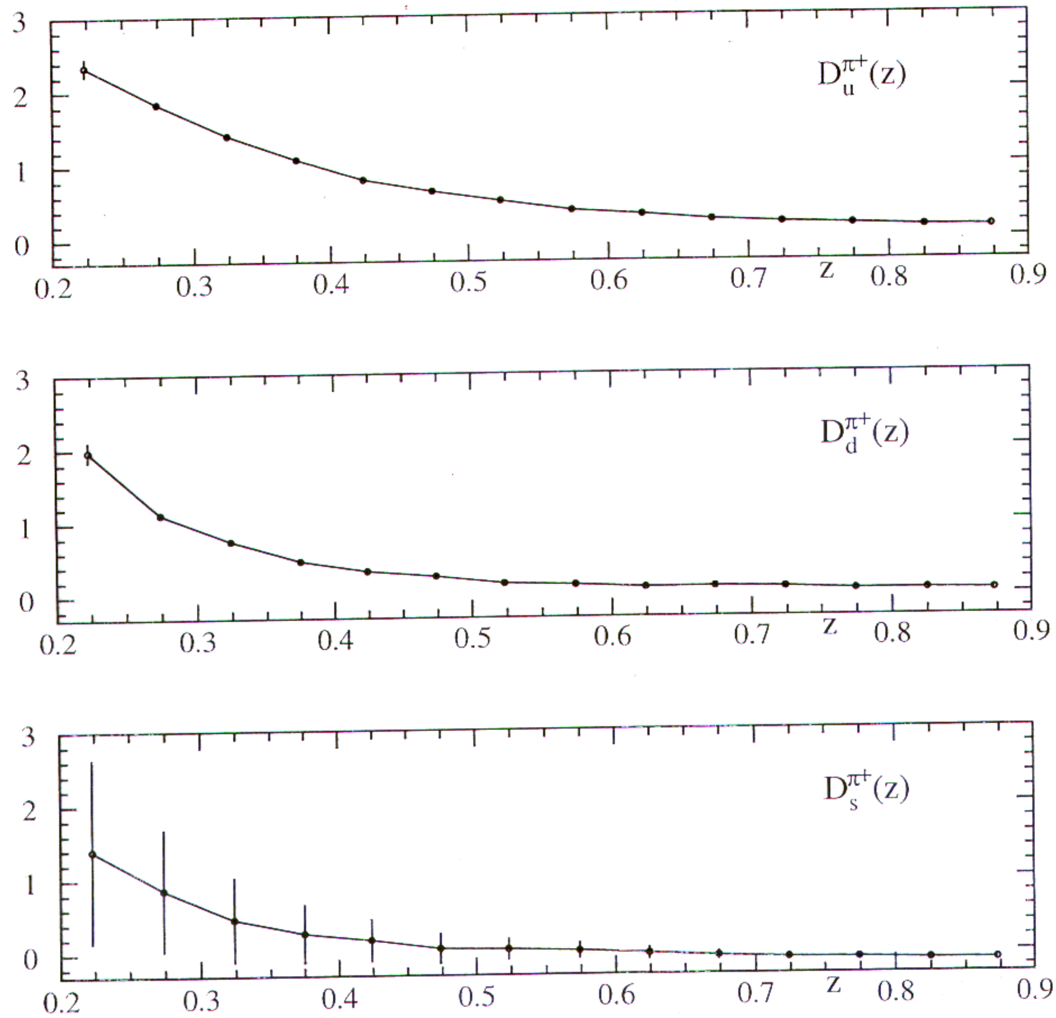

Figure 3: The extracted fragmentation functions with errors which combine the experimental errors from [4] with a typical 20% uncertainty arising from the evolution of the singlet fragmentation function.

Kretzer, Leader, Christova : hep-ph/0108055
EUR. PHYS. J. C22 (2001) 269

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A FINAL WORD ----

DEAR COMPASS

and

DEAR HERMES,

Please provide us with

1) UNPOLARIZED MULTIPLICITIES WITH GOOD PARTICLE IDENTIFICATION, SO THAT WE CAN DETERMINE FRAGMENTATION FUNCTIONS

and

2) POLARIZED MULTIPLICITIES WITH GOOD PARTICLE IDENTIFICATION, SO THAT WE CAN DETERMINE $\Delta\bar{u}$, $\Delta\bar{d}$ ---

SOON!