LEPTO & Polarized SIDIS

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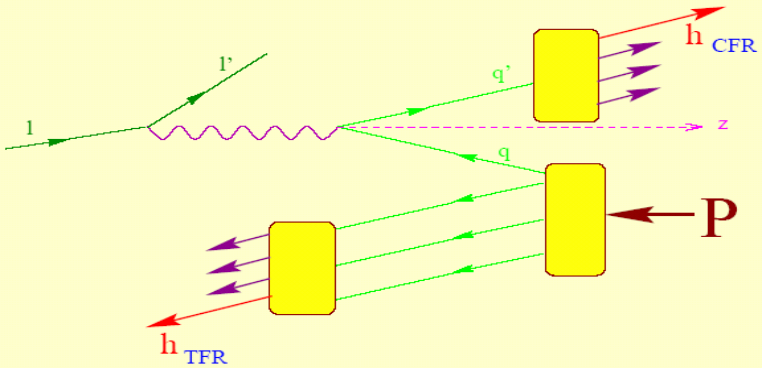
On leave of absence from YerPhI, Armenia and JINR, Russia

- (polarized) SIDIS
  - Independent fragmentation
    - ***Purity*** method for polarized quark DF extraction
  - LEPTO
    - Lund fragmentation
  - New framework for SIDIS
    - ***polarized*** "Lund Hadronization Functions" (AK, hep-ph/0410093)
- Discussion & Conclusions

SIDIS



Virtual boson – nucleon CMS:

$x_F > 0$ – current fragmentation (CFR)

$x_F < 0$ – target fragmentation (TFR)

Commonly used framework: for hadrons with z>0.2 ➡ the parton model with independent quark fragmentation

$$\sigma^h(x,Q^2,z) \propto (1+(1-y)^2)\sum_q e_q^2\, q(x,Q^2)\, D_q^h(z,Q^2)$$

$$\Delta\sigma^h(x,Q^2,z) \propto (1-(1-y)^2)\sum_q e_q^2\, \Delta q(x,Q^2)\, D_q^h(z,Q^2)$$

$$A_1^h(x,Q^2,z) = \frac{\sum_q e_q^2\, \Delta q(x,Q^2)\, D_q^h(z,Q^2)}{\sum_q e_q^2\, q(x,Q^2)\, D_q^h(z,Q^2)}$$

$$A_1^h(x,Q^2,z) = \sum_q \mathcal{P}_q^h(x,Q^2,z)\,\frac{\Delta q(x,Q^2)}{q(x,Q^2)} \qquad \mathcal{P}_q^h(x,Q^2,z) = \frac{e_q^2\, q(x,Q^2)\, D_q^h(z,Q^2)}{\sum_{q'} e_{q'}^2\, q'(x,Q^2)\, D_{q'}^h(z,Q^2)}$$

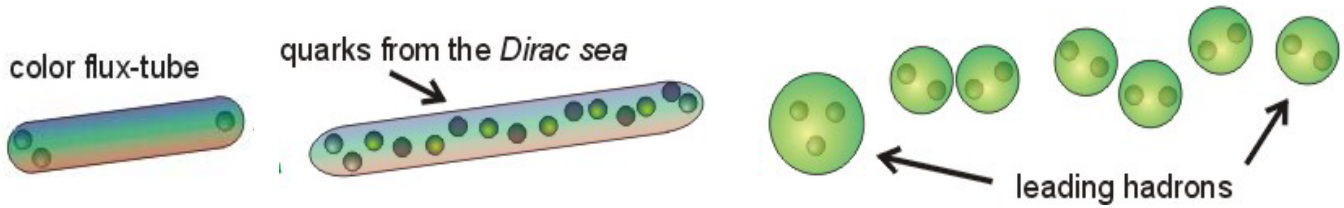
Purities are calculated using LEPTO

LO SIDIS in LEPTO

- Before 

- After Target remnant quark

-Example: valence struck quark



Natural question: does Lund hadronization exactly correspond to independent quark fragmentation in the CFR with z>0.2?
The important property of FFs is universality:

1. Independence of Bjorken variable *x*
2. Target type independence
3. Process type independence

$$D_q^h(z,Q^2) = \frac{N_{q/N}^{h,SIDIS}(x,z,Q^2)}{N_{q/N}^{DIS}(x,z,Q^2)}$$

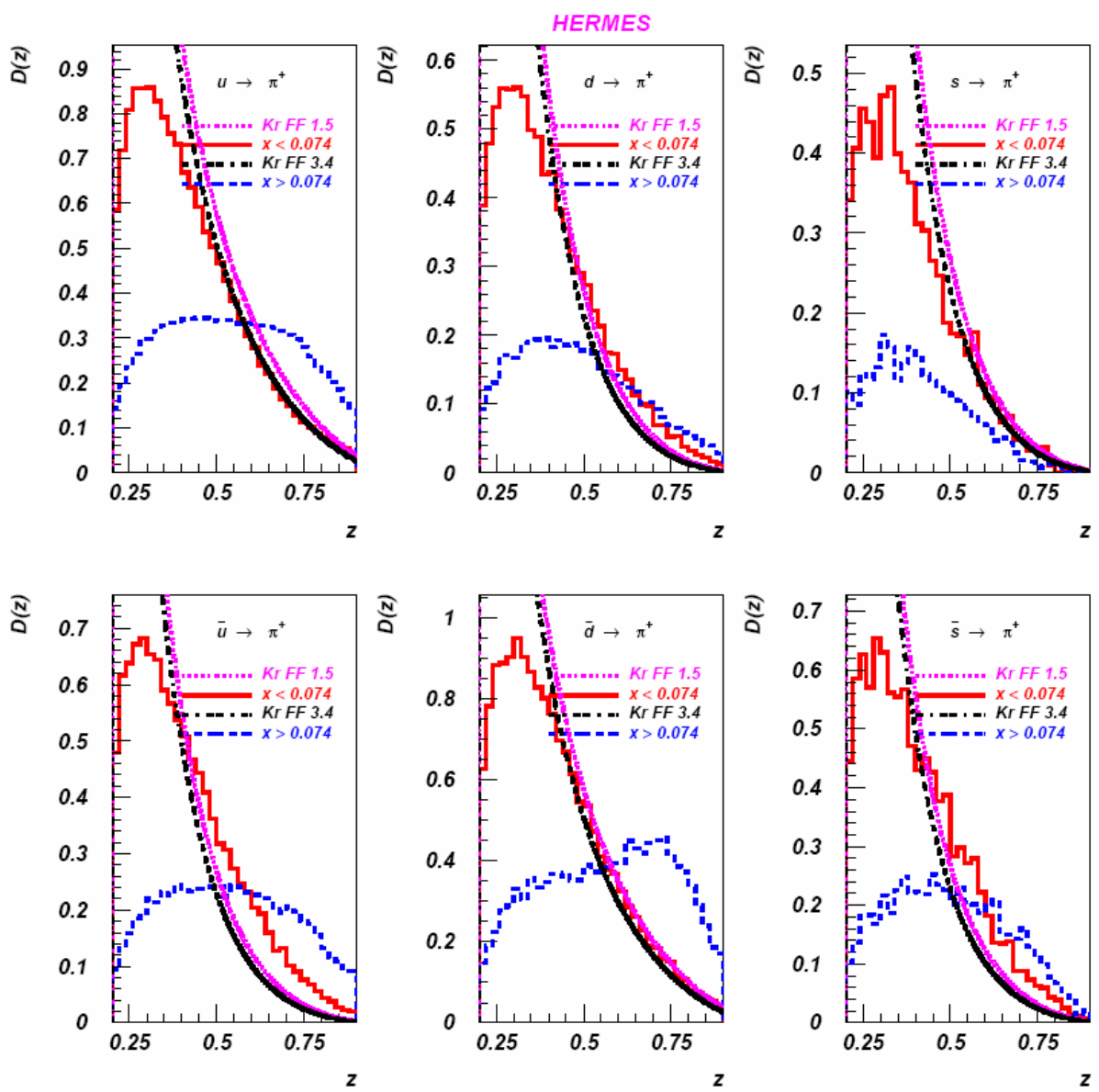
Bjorken variable dependence of “FFs” in LEPTO

$x < 0{,}074$

$Q^2 = 1.5 GeV^2$

$x > 0{,}074$

$Q^2 = 3.4 GeV^2$

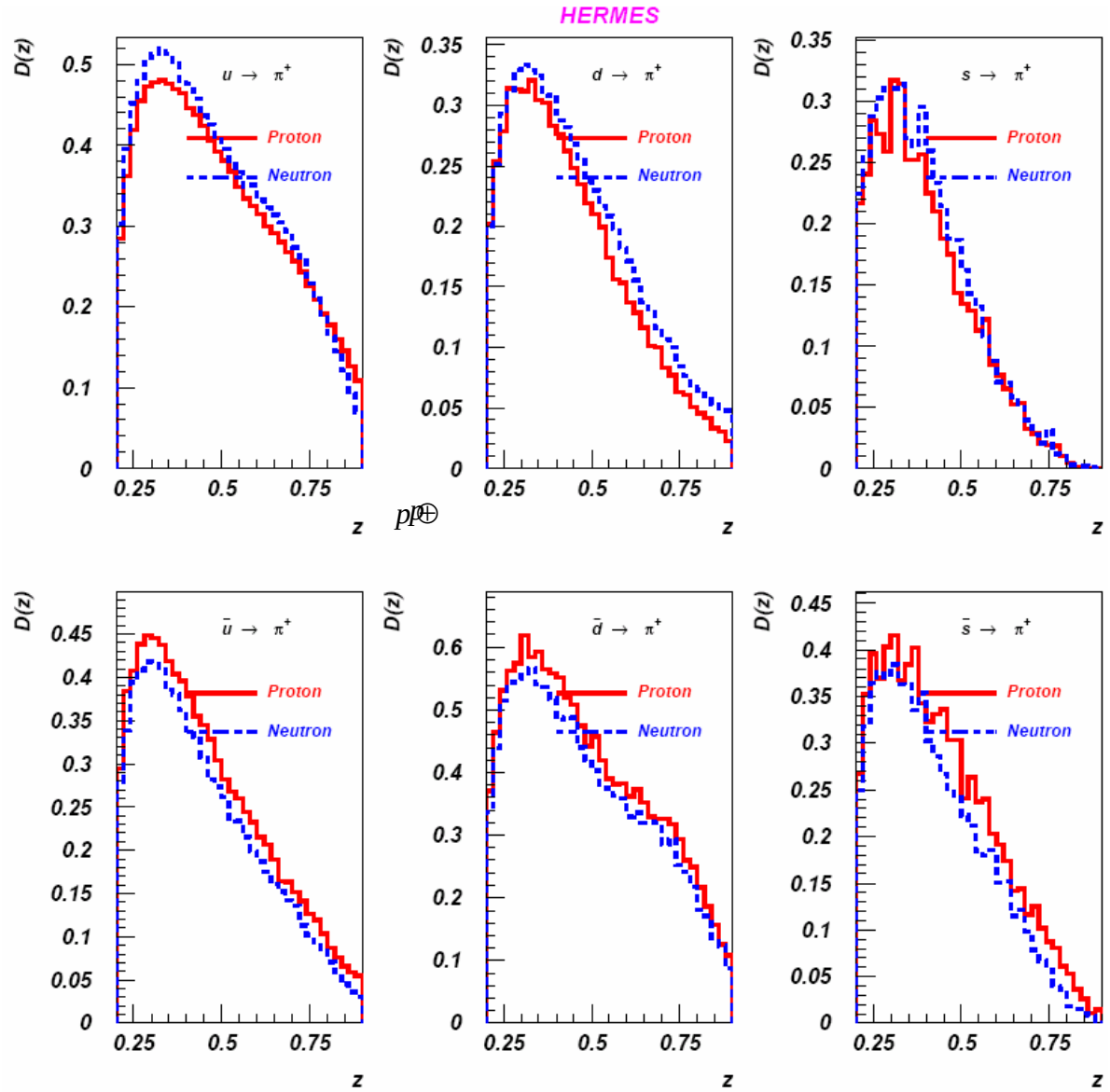


Target type dependence of "FFs" in LEPTO

Example of target remnant: removed valence ***u***-quark:

$$p - u \Rightarrow (ud)$$

$$n - u \Rightarrow (dd)$$



LUND string fragmentation

The primary hadrons produced in string fragmentation come from the string as a whole, rather than from an individual parton.

PYTHIA 6.2

Physics and Manual

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LUND Hadronization Functions (LHF)

Even for meson production in the CFR LEPTO does not correspond to SIDIS description within FFs $D_q^h(z,Q^2)$ framework

We are dealing with LUND hadronization functions: $H_{q/N}^h(x,z,Q^2)$

$$\sigma_N^h(x,z,Q^2) \propto (1+(1-y)^2)\sum_q e_q^2\, q(x,Q^2)\, H_{q/N}^h(x,z,Q^2)$$

More general framework -- Fracture Functions (Teryaev, T-odd, SSA…)

$$M_{q/N}^h(x,x_F,Q^2)$$

LEPTO is a model for Fracture Functions:

$$M_{q/N}^h(x,x_F,Q^2) = q(x,Q^2)H_{q/N}^h(x,x_F,Q^2)$$

Violation of naïve *x*-*z* factorization and isotopic invariance

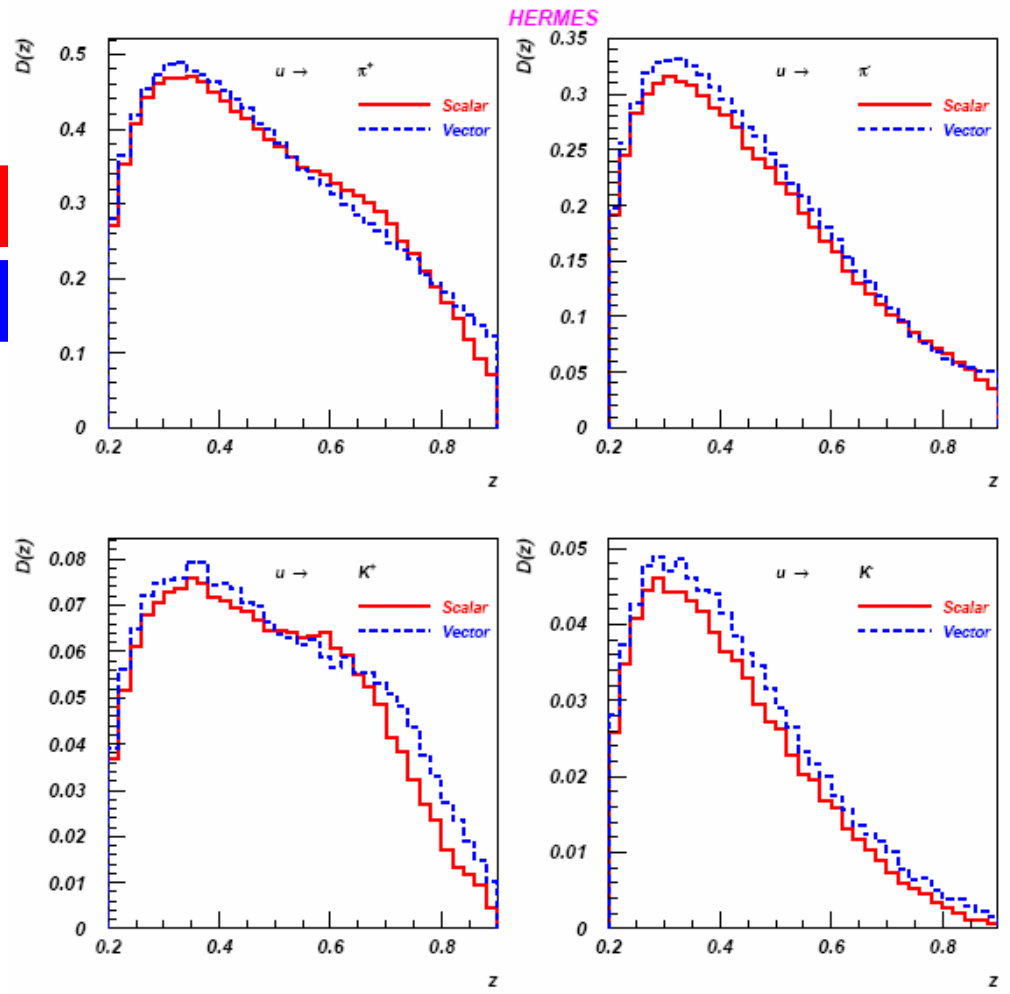
The dependence on target flavor is due to dependence on target remnant flavor quantum numbers. What about spin quantum numbers?

Dependence on target remnant spin state (unpolarized LEPTO)

Example: valence ***u***-quark is removed from proton. Default LEPTO: the remnant (***ud)*** diquark is in 75% (25%) of cases scalar (vector)

$\{(ud)_0 \cdots\cdots u\}, \quad w = 1.$

$\{(ud)_1 \cdots\cdots u\}, \quad w = 1.$



Even in unpolarized LEPTO there is a dependence on target remnant spin state

Target remnant in Polarized SIDIS

JETSET is based on SU(6) quark-diquark model

$$p^+ = \frac{1}{\sqrt{18}}\{u^+[3(ud)_{0,0} + (ud)_{1,0}] - \sqrt{2}u^-(ud)_{1,1} - \sqrt{2}d^+(uu)_{1,0} + 2d^-(uu)_{1,1}\}$$

$$n^+ = \frac{1}{\sqrt{18}}\{d^+[3(ud)_{0,0} + (ud)_{1,0}] - \sqrt{2}d^-(ud)_{1,1} - \sqrt{2}u^+(dd)_{1,0} + 2u^-(dd)_{1,1}\}$$

$$p^+ \ominus u^+ \Longrightarrow \begin{cases} \{(ud)_{0,0} \cdot \cdot \cdot \cdot \cdot u^+\}, & w = 0.9 \\ \{(ud)_{1,0} \cdot \cdot \cdot \cdot \cdot u^+\}, & w = 0.1 \end{cases}$$

90% scalar

$$p^- \ominus u^+ \Longrightarrow \{(ud)_{1,-1} \cdot \cdot \cdot \cdot \cdot u^+\}, \quad w = 1$$

100% vector

$$n^+ \ominus u^+ \Longrightarrow \{(dd)_{1,0} \cdot \cdot \cdot \cdot \cdot u^+\}, \quad w = 1$$

$$n^- \ominus u^+ \Longrightarrow \{(dd)_{1,-1} \cdot \cdot \cdot \cdot \cdot u^+\}, \quad w = 1$$

Probabilities of different target remnant spin states depend on quark and target polarizations and types!

Polarized SIDIS & LHF

$\sigma^h_{N\,\lambda_l\lambda_N}$ and $H^h_{q/N\,\lambda_q\lambda_N}$ -- spin dependent cross section and LHFs

$$\sigma^h_{N++} \propto \sum_q e_q^2\{q^+\, H^h_{q/N++} + (1-y)^2 q^-\, H^h_{q/N-+}\}$$
$$\sigma^h_{N+-} \propto \sum_q e_q^2\{q^-\, H^h_{q/N+-} + (1-y)^2 q^+ H^h_{q/N--}\}$$

$$H^h_{q/N} = H^h_{q/N++} + H^h_{q/N+-}$$
$$\Delta H^h_{q/N} = H^h_{q/N++} - H^h_{q/N+-}$$

$$\sigma^h_{N\lambda_l\lambda_N} \propto [1+(1-y)^2]\sum_q e_q^2\{qH^h_{q/N} + \Delta q \Delta H^h_{q/N}\} +$$
$$\lambda_l\lambda_N[1-(1-y)^2]\sum_q e_q^2\{\Delta q H^h_{q/N} + q\Delta H^h_{q/N}\},$$

These Eqs. coincide with those proposed by Gluk&Reya (polarized FFs) in contrast with FFs, LHFs in addition to ***z*** depend on ***x and target type:***

non-universality

Asymmetry

$$A_1^h(x,z,Q^2) = \frac{\sum_q e_q^2 q(x,Q^2) H_{q/N}^h(x,z,Q^2)\left(\frac{\Delta q(x,Q^2)}{q(x,Q^2)} + \frac{\Delta H_{q/N}^h(x,z,Q^2)}{H_{q/N}^h(x,z,Q^2)}\right)}{\sum_q e_q^2 q(x,Q^2) H_{q/N}^h(x,z,Q^2)\left(1 + \frac{\Delta q(x,Q^2)\Delta H_{q/N}^h(x,z,Q^2)}{q(x,Q^2) H_{q/N}^h(x,z,Q^2)}\right)}$$

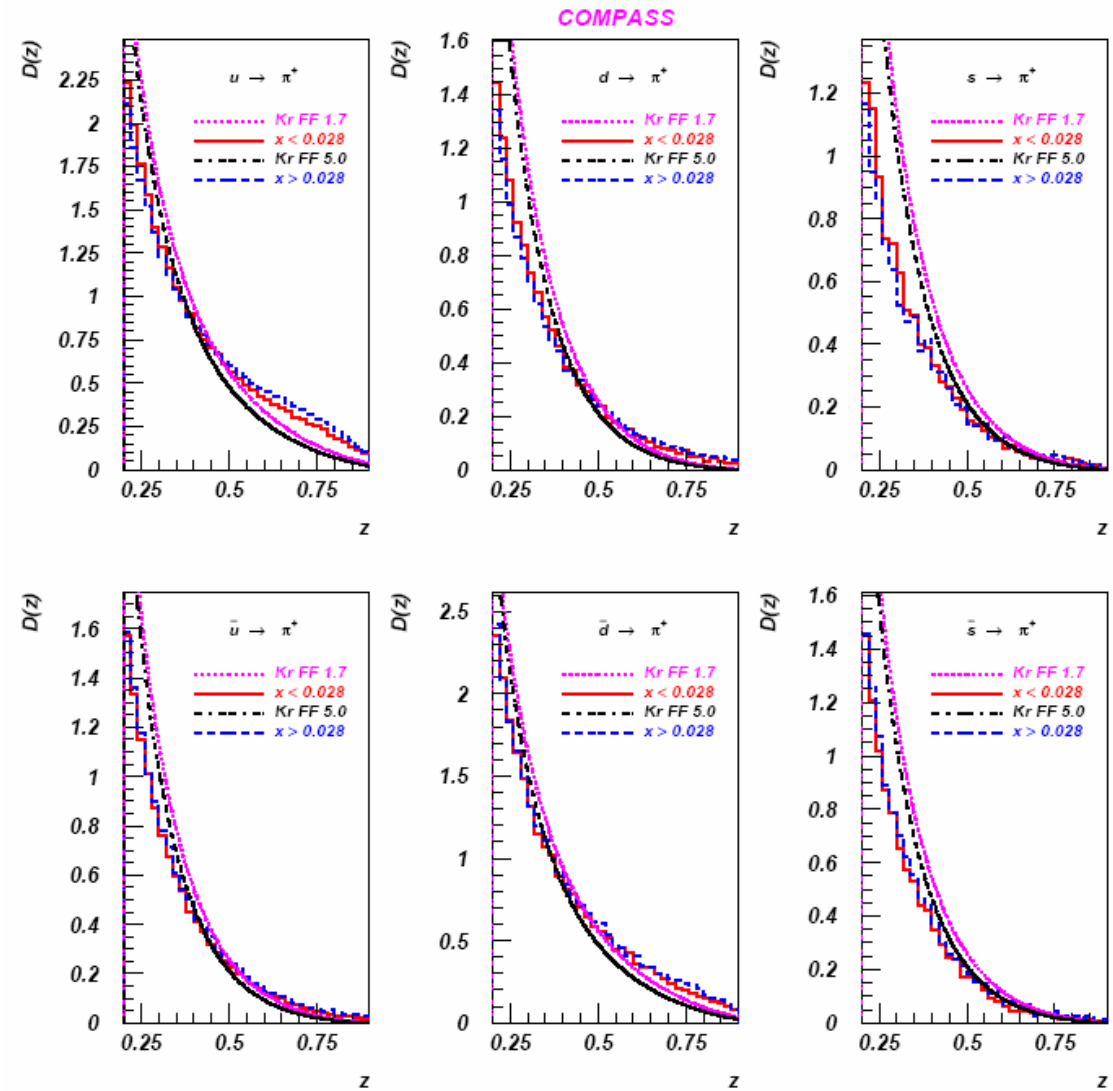
The standard expression for SIDIS asymmetry is obtained when

$$H_{q/N}^h(x,z,Q^2) \to D_q^h(z,Q^2) \qquad \Delta H_{q/N}^h(x,z,Q^2) \to 0.$$

For validity of purity method most important is the second relation

Positivity: $$\frac{\left|\Delta H_{q/N}^h\right|}{H_{q/N}^h} \le 1$$

Energy Dependence



Situation is different for higher energies: dependencies of "FFs" extracted from MC on ***x, target type and target remnant quantum numbers*** **are weaker**

Some conclusions

- SIDIS description in LEPTO do not exactly correspond to simple LO ***x-z factorized*** picture for SIDIS.
  - Expression for SIDIS x-section contains additional nonperturbative input: LHFs
- There is no reason to believe that ***polarized*** LHFs =0 at moderate energies
  - Purity method of HERMES is based on misleading identification of physics included in LEPTO MC code with naive parton model picture of SIDIS.
    - The results on polarized DFs obtained with this method can not be considered precise.
  - Validity of the MC based approach for ΔG extraction may also be questionable at moderate energies.
- More studies on the accuracy of different methods of the polarized quark DF extraction using SIDIS asymmetries are needed.
- Alternative measurements are highly desirable
  - ***W*** production in polarized ***p+p*** collisions
  - ***(Anti)neutrino*** DIS on ***polarized targets*** (neutrino factory)