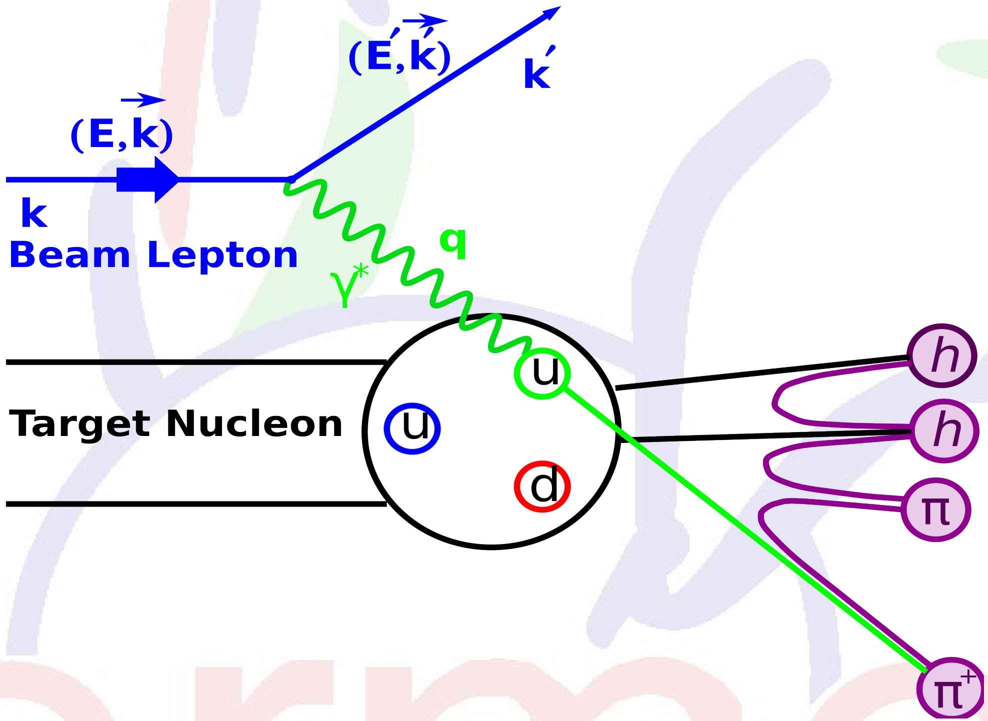
Hadron multiplicities at the HERMES experiment

Gevorg Karyan
on behalf of the HERMES Collaboration

Alikhanyan National Science Laboratory
Yerevan, Armenia

Semi-Inclusive Deep-Inelastic Scattering

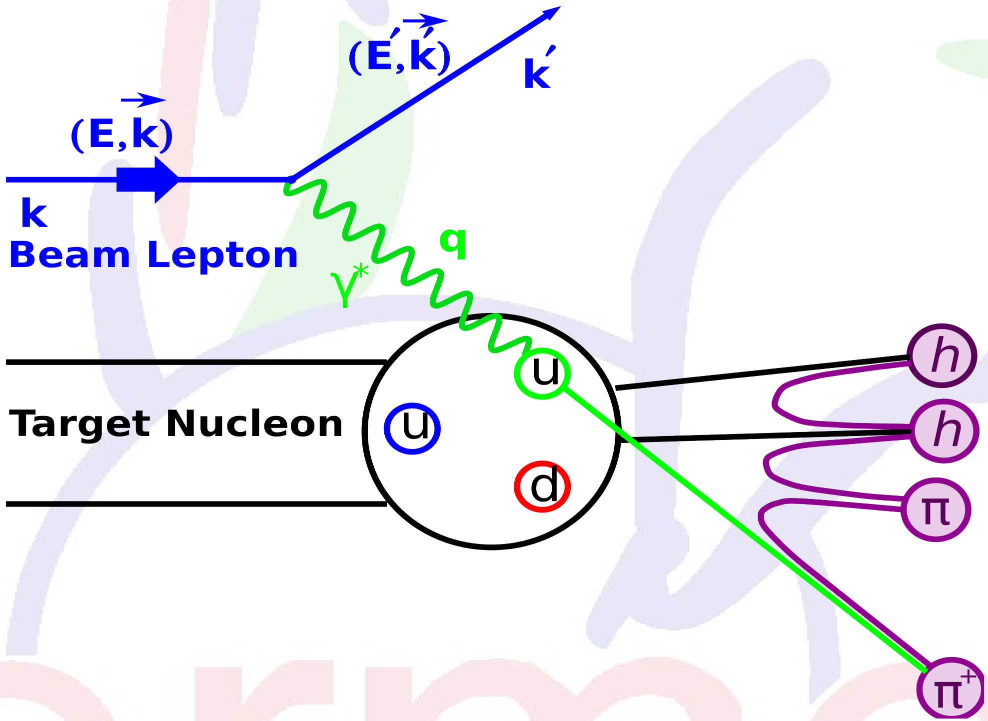


Semi-Inclusive Deep-Inelastic Scattering

$$Q^2 = -(k - k')^2$$

$$\nu = E - E'$$

$$W^2 = (M_N + q)^2$$



$$x_B = \frac{Q^2}{2 \cdot M_N \cdot \nu}$$

$$z = E_h / \nu$$

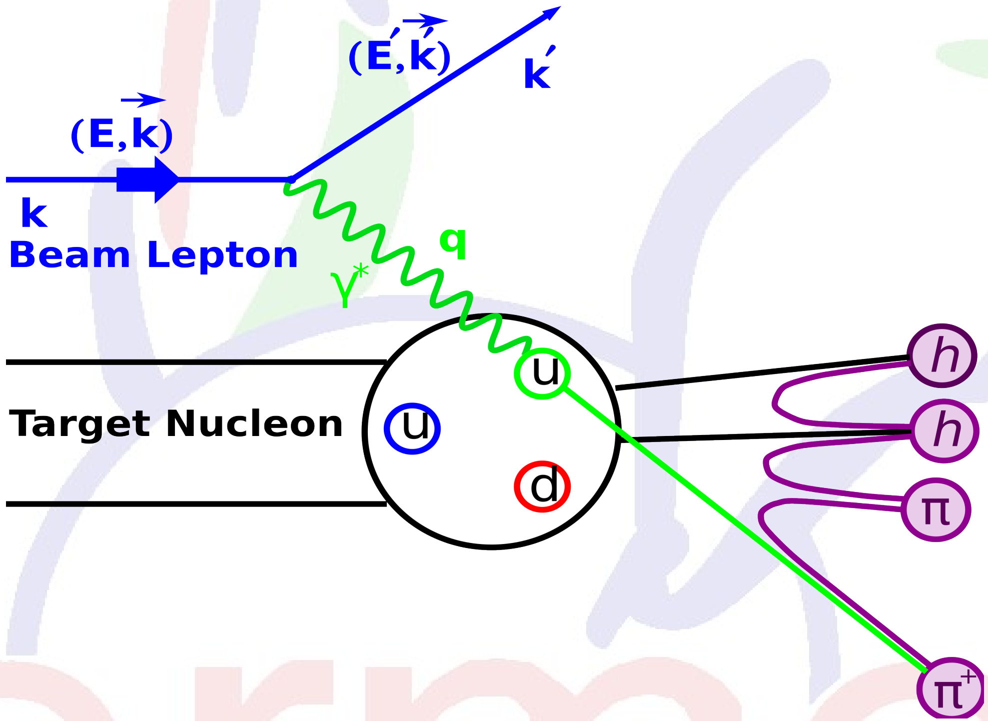
$$P_{h\perp} = \frac{|\vec{P}_h \times \vec{q}|}{|\vec{q}|}$$

Semi-Inclusive Deep-Inelastic Scattering

$$Q^2 = -(k - k')^2$$

$$\nu = E - E'$$

$$W^2 = (M_N + q)^2$$



$$x_B = \frac{Q^2}{2 \cdot M_N \cdot \nu}$$

$$z = E_h / \nu$$

$$P_{h\perp} = \frac{|\vec{P}_h \times \vec{q}|}{|\vec{q}|}$$

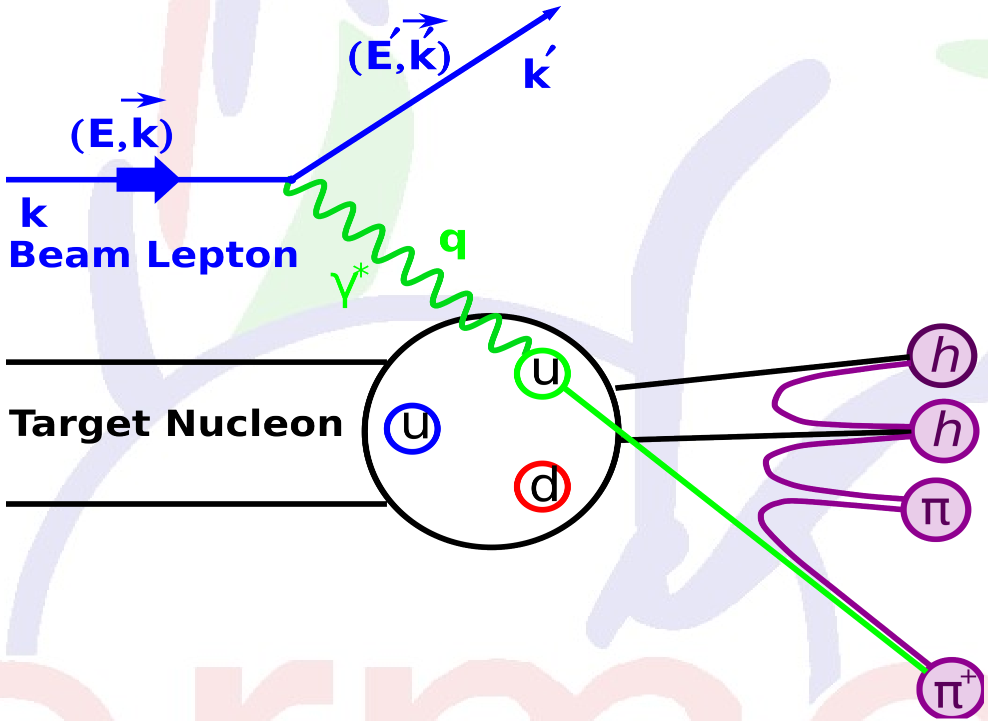
Leading Order QCD, Factorization

Semi-Inclusive Deep-Inelastic Scattering

$$Q^2 = -(k - k')^2$$

$$\nu = E - E'$$

$$W^2 = (M_N + q)^2$$



$$x_B = \frac{Q^2}{2 \cdot M_N \cdot \nu}$$

$$z = E_h / \nu$$

$$P_{h\perp} = \frac{|\vec{P}_h \times \vec{q}|}{|\vec{q}|}$$

$$\sigma_{eN \to ehX} \sim \sum_f e_f^2 q_f(x_B, Q^2, p_T)\, \sigma^{eq \to eq} D_f^h(z, Q^2, k_T)$$

Experimental observable

SIDIS hadron yields

$$M^h(x_B, Q^2, z, P_{h\perp}, \phi) = \frac{N^h(x_B, Q^2, z, P_{h\perp}, \phi)}{N^e(x_B, Q^2)}$$

DIS event yields

Underlying physics

$$M^h \sim \frac{\sum_f e_f^2 \, q_f(x_B, Q^2, p_T) \, D_f^h(z, Q^2, k_T)}{\sum_f e_f^2 \, q_f(x_B, Q^2, p_T)}$$

Underlying physics

$$M^h \sim \frac{\sum_f e_f^2\, q_f\left(x_B, Q^2, p_T\right) D_f^h\left(z, Q^2, k_T\right)}{\sum_f e_f^2\, q_f\left(x_B, Q^2, p_T\right)}$$

PDF

PDF

Underlying physics

$$M^h \sim \frac{\sum_f e_f^2\, q_f(x_B, Q^2, p_T)\, D_f^h(z, Q^2, k_T)}{\sum_f e_f^2\, q_f(x_B, Q^2, p_T)}$$

PDF FF

PDF

Underlying physics

Collinear Framework

$$M^h \sim \frac{\sum_f e_f^2 \, q_f(x_B, Q^2) \, D_f^h(z, Q^2)}{\sum_f e_f^2 \, q_f(x_B, Q^2)}$$

PDF FF

PDF

PDFs are well known

FFs are poorly known

Underlying physics

$$M^h \sim \frac{\sum_f e_f^2 \, q_f(x_B, Q^2) \, D_f^h(z, Q^2)}{\sum_f e_f^2 \, q_f(x_B, Q^2)}$$

PDF FF

PDF

PDFs are well known

FFs are poorly known

Particularly unfavored FFs

Underlying physics

$$M^h \sim \frac{\sum_f e_f^2 \, q_f\left(x_B, Q^2\right) D_f^h\left(z, Q^2\right)}{\sum_f e_f^2 \, q_f\left(x_B, Q^2\right)}$$

PDF · FF · PDF

CTEQ6L, GRV, …

DSS, Kretzer, …

Universality

SIDIS(e+N), SIA(e^++e^-), HS(p+p)

Advantage of SIDIS

Charge separated FFs

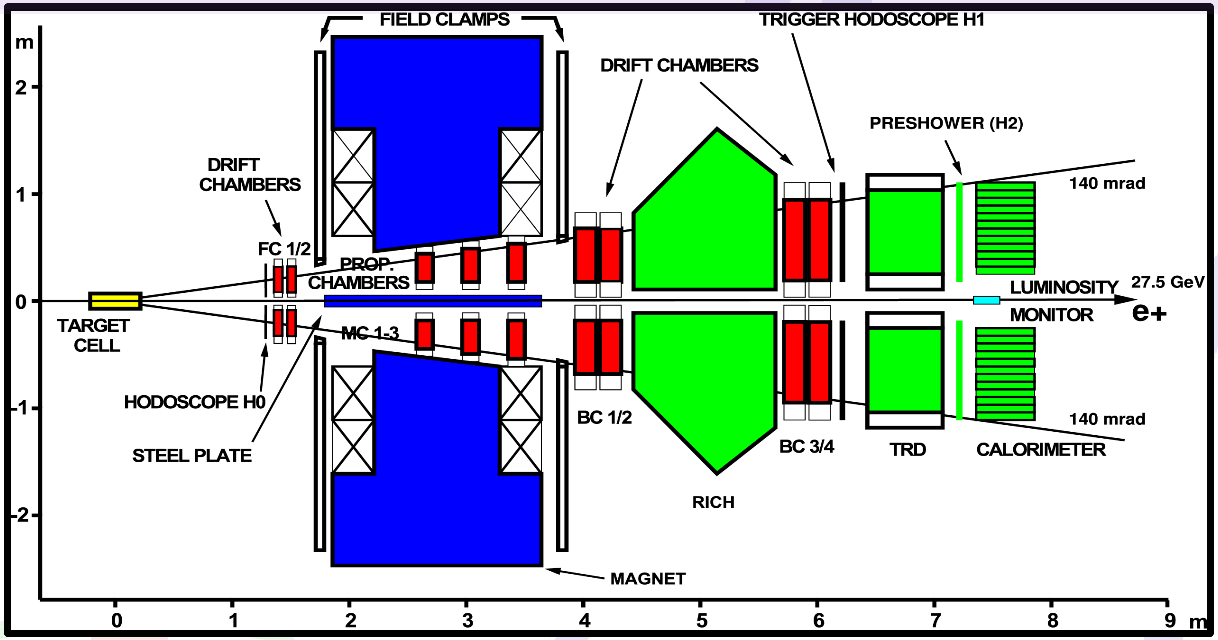
$(D_u^{\pi}, D_{\bar{u}}^{K}, \ldots)$

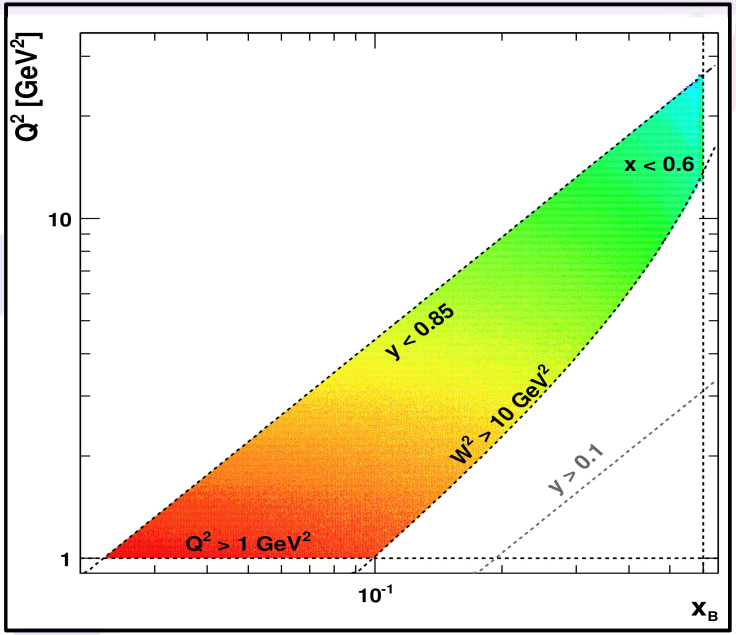
SIDIS

$(D_u^{\pi}, D_s^{K}, \ldots)$

Flavour separated FFs

Experiment





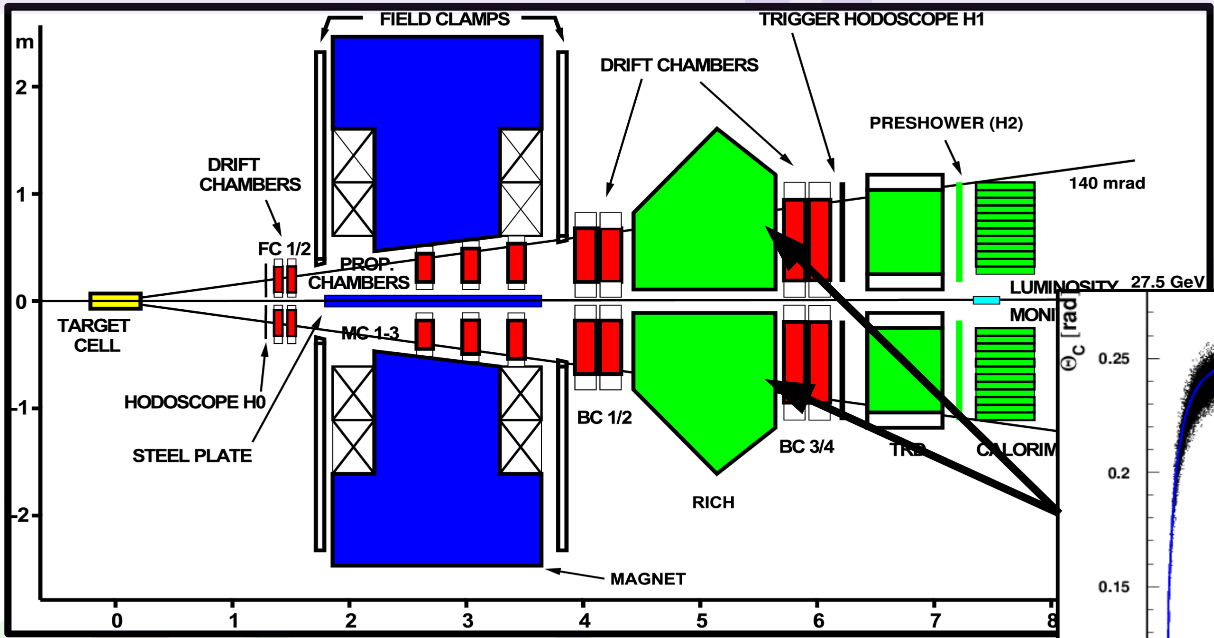
Beam : e^-/e^+ 27.6 GeV

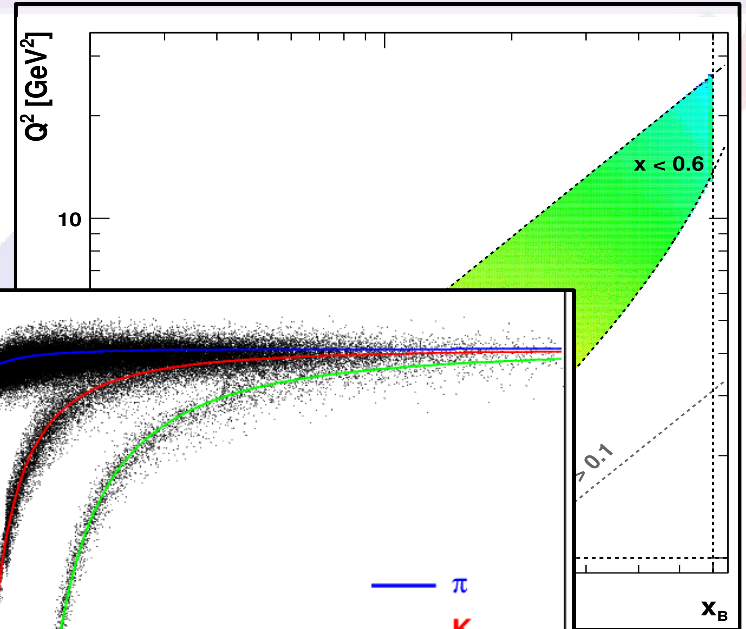
Target : H/D pure gaseous

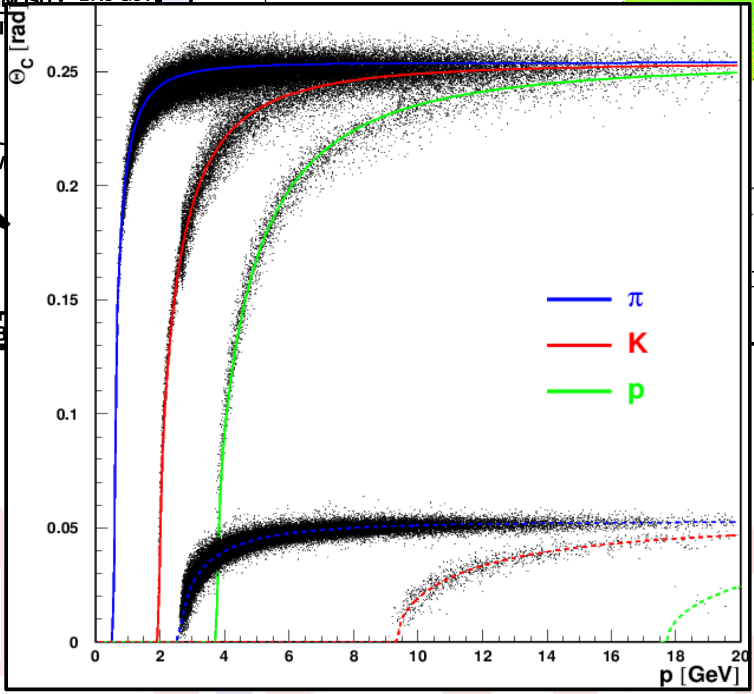
Good momentum resolution : $\frac{\delta p}{p} < 2\ \%$

Excellent particle identification

Experiment







Beam : e^-/e^+ 27.6 GeV

Target : H/D pure gaseous

Good momentum resolution :

Excellent particle identification

Data selection

DIS regime

- $Q^2 > 1$ GeV ^{2}
- $W^2 > 10$ GeV ^{2}
- $0.1 < \nu/E_{beam} < 0.85$

SIDIS selection

- 2 GeV < p < 15 GeV
- 0.2 < z < 0.8

Raw Data

Data analysis

Raw Data

Charge Symmetric Background (Dalitz decay, $\gamma \to e^+e^-$)

RICH Unfolding

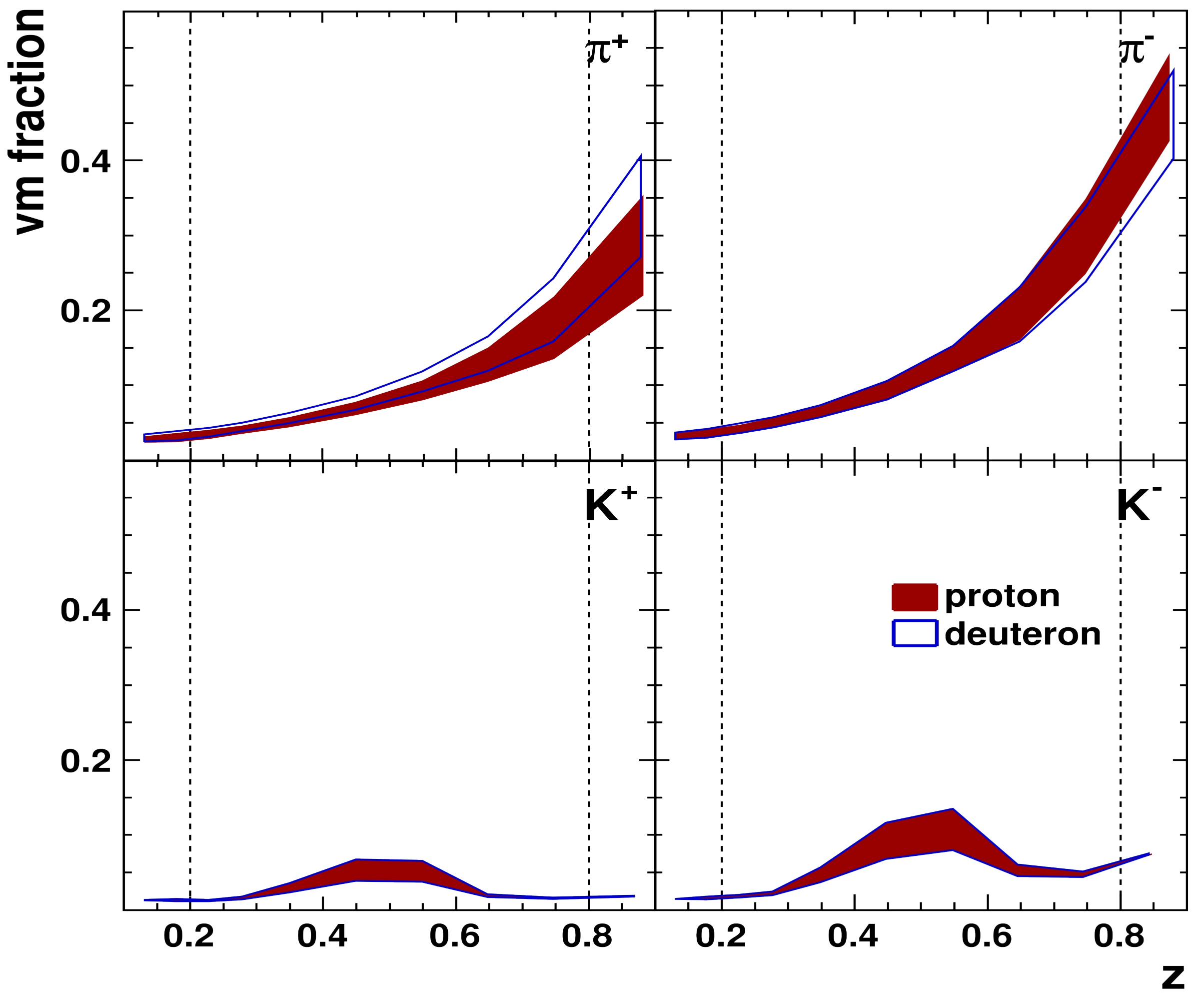
Trigger Efficiencies

Diffractive Vector Meson Contribution

Detector Smearing & QED Radiative Effects

Final Data

Exclusive vector meson contribution



Due to diffractively produced exclusive $\rho^0 \to \pi^+\pi^-$ and $\phi \to K^+K^-$

- **Results with and without VM subtraction**

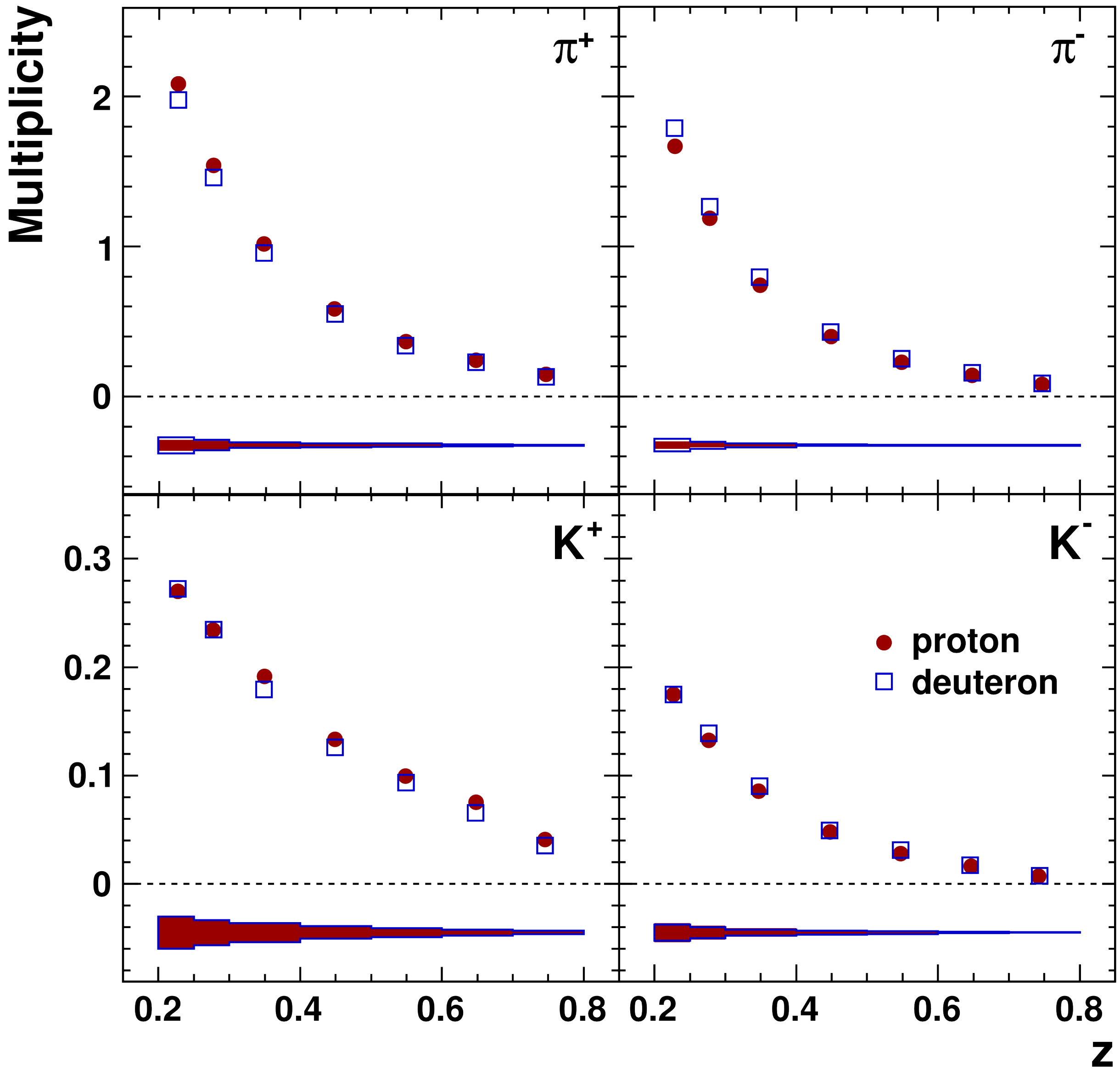
Results

arXiv:1212.5407v1

A. Airapetian et al, Phys. Rev. D87 (2013) 074029

- **In this presentation results are with VM subtraction.**

$M^h(x_B, Q^2, z, P_{h\perp})$



$u \rightarrow \pi^+(u\bar{d})$ **favored**

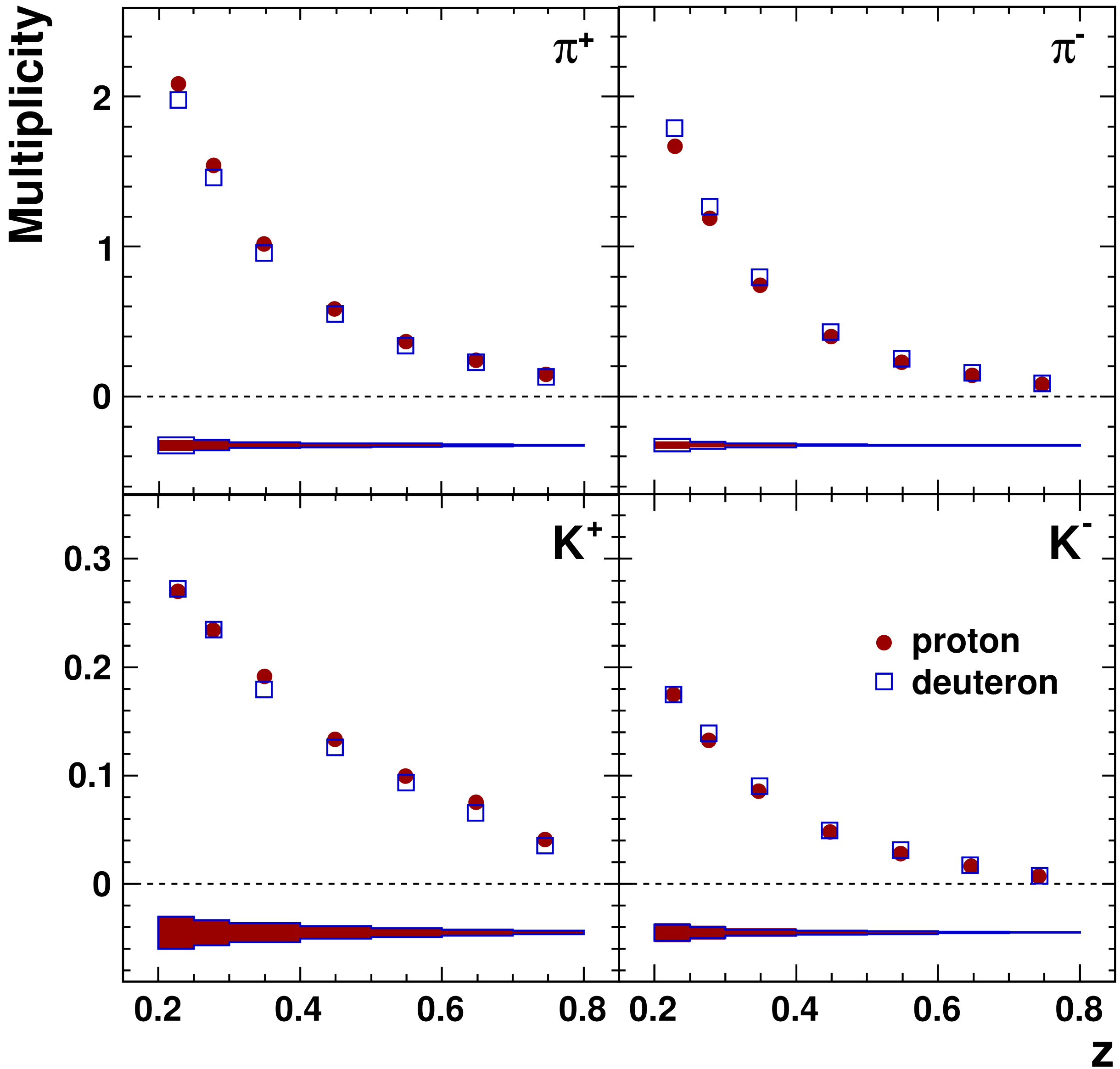
$u \rightarrow \pi^-(d\bar{u})$ **unfavored**

proton → u dominance

$$\frac{M^{\pi^+}_{proton}}{M^{\pi^-}_{proton}} = 1.2 - 2.6$$

$d \rightarrow \pi^-$ **favored**

$$\frac{M^{\pi^-}_{deuteron}}{M^{\pi^-}_{proton}} > 1$$



$M^h(x_B, Q^2, z, P_{h\perp})$

$u \rightarrow K^+(u\bar{s})$ **favored**

$u \rightarrow K^-(s\bar{u})$ **unfavored**

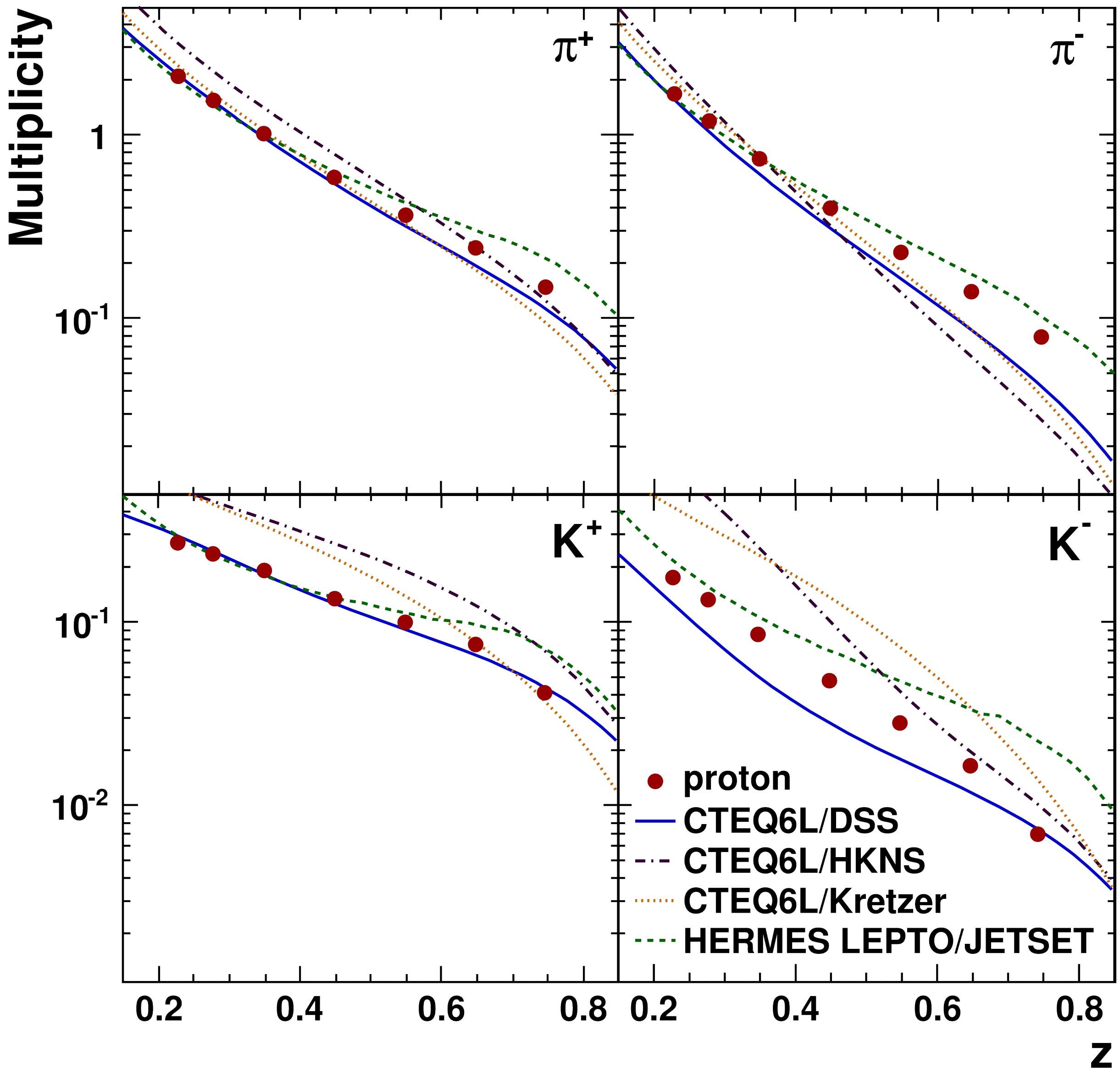
proton → u dominance

$$\frac{M^{K^+}_{proton}}{M^{K^-}_{proton}} = 1.5 - 5.7$$

K^- : **sea object**

$$M^{K^-}_{deuteron} \simeq M^{K^-}_{proton}$$

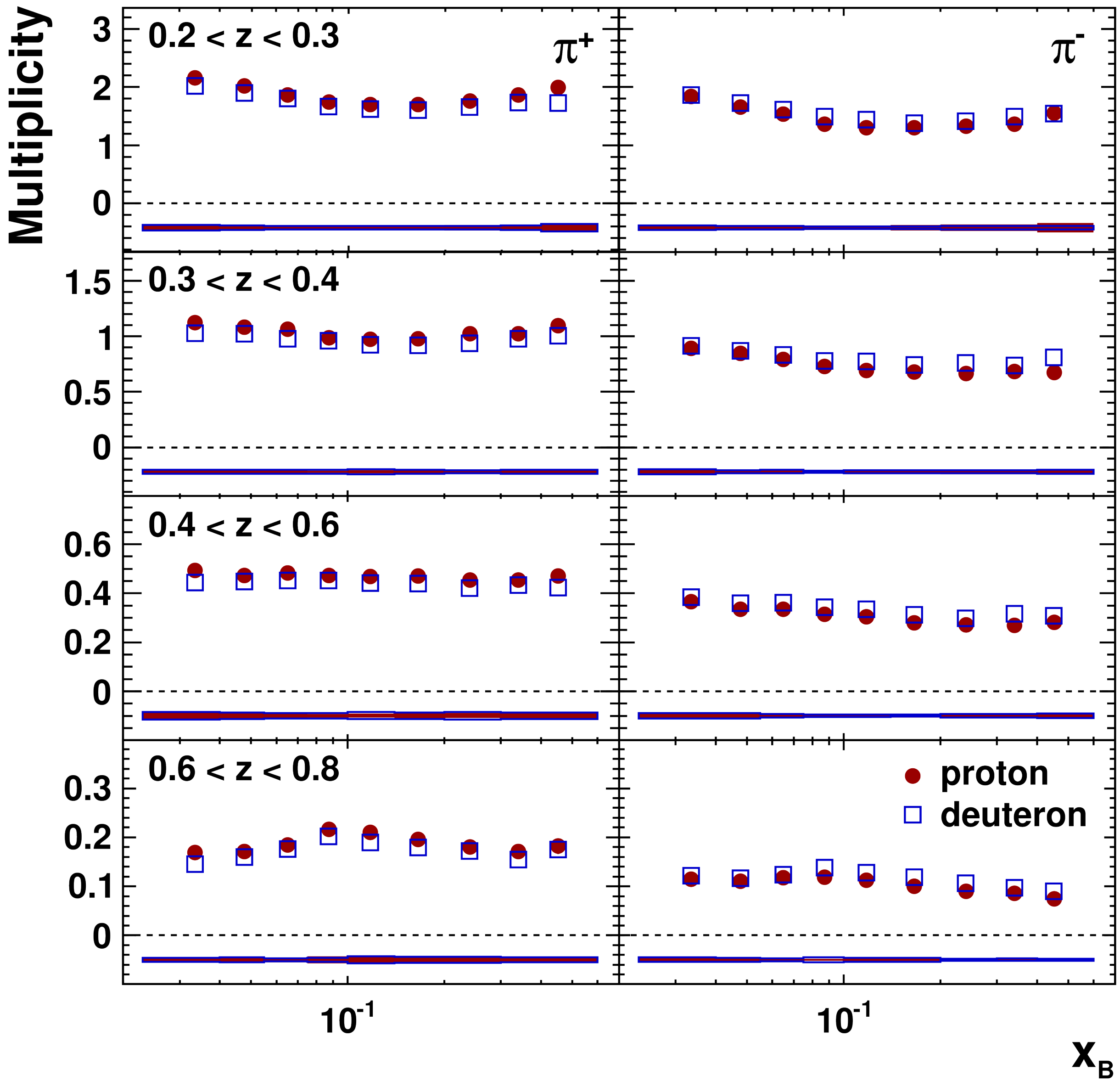
$M^h(x_B, Q^2, z, P_{h\perp})$



LO calculations

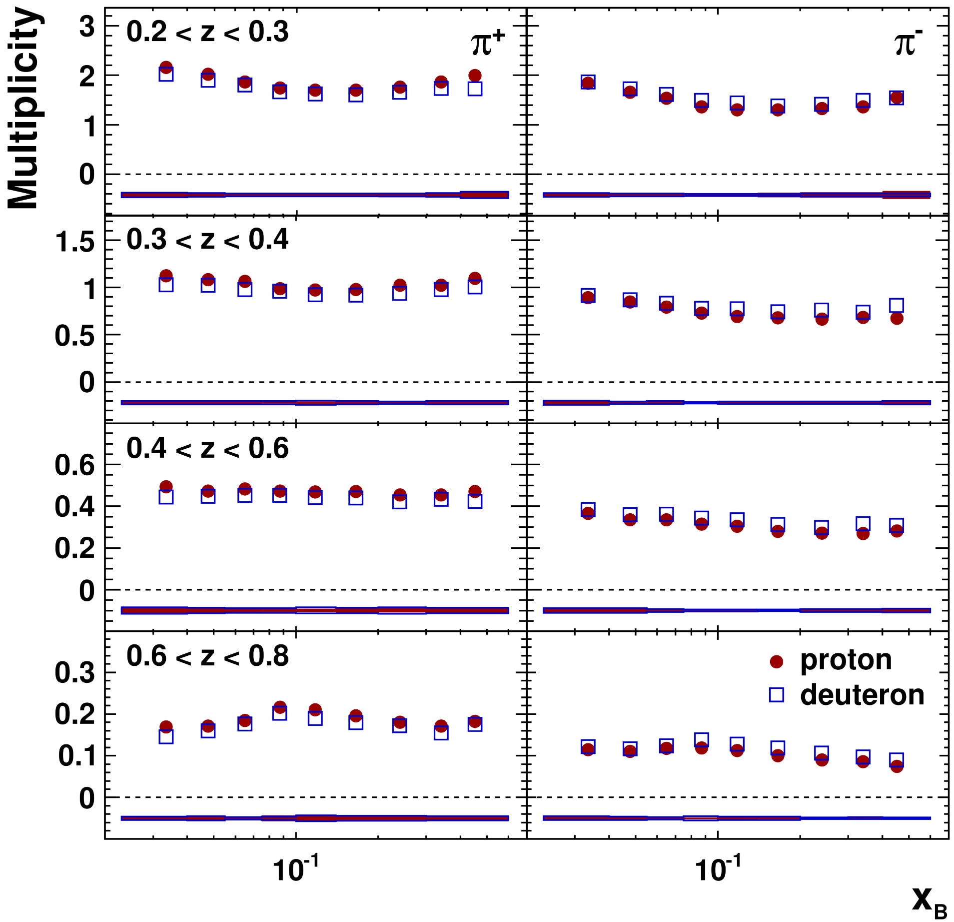
- **Reasonable agreement between DSS FFs and Data for positively charged pions and kaons.**
- **Substantial differences between all FFs and Data for negatively charged kaons.**

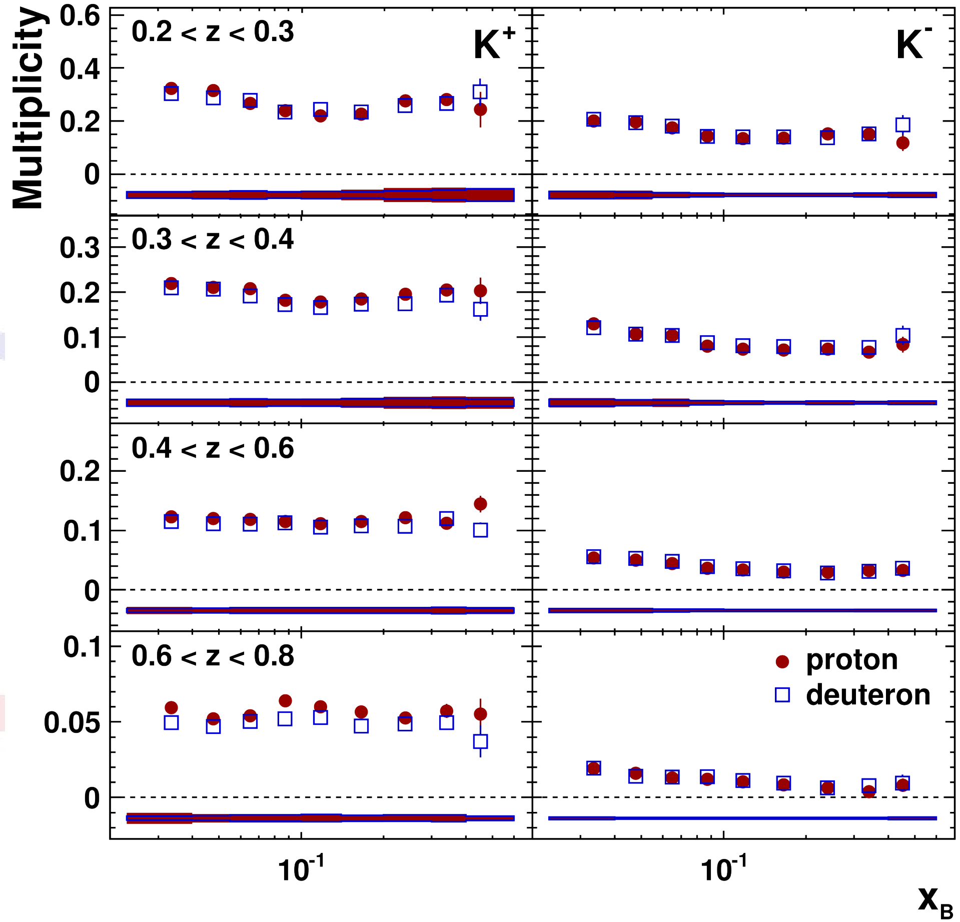
$M^h(x_B, Q^2, z, P_{h\perp})$



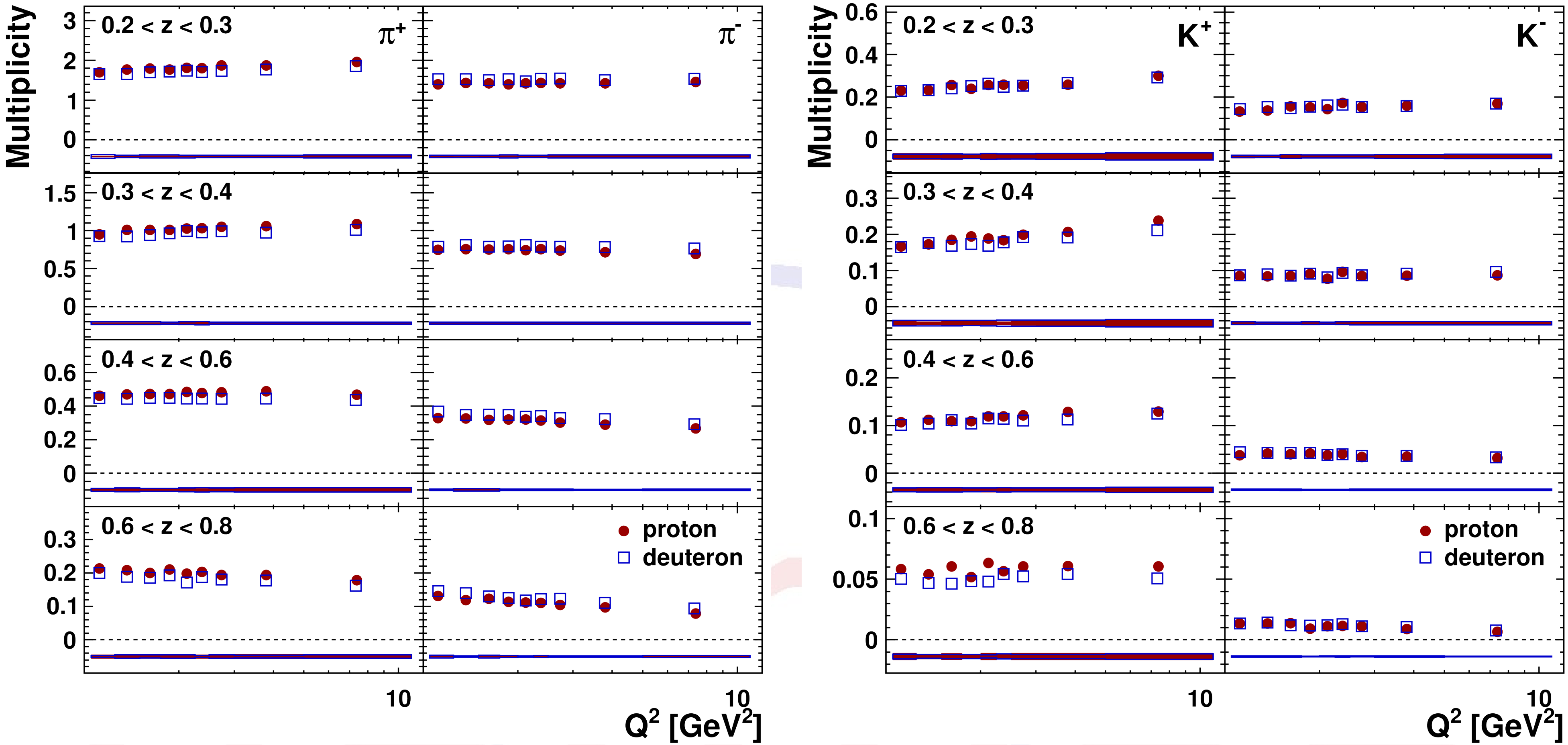
Almost no dependence on x_B

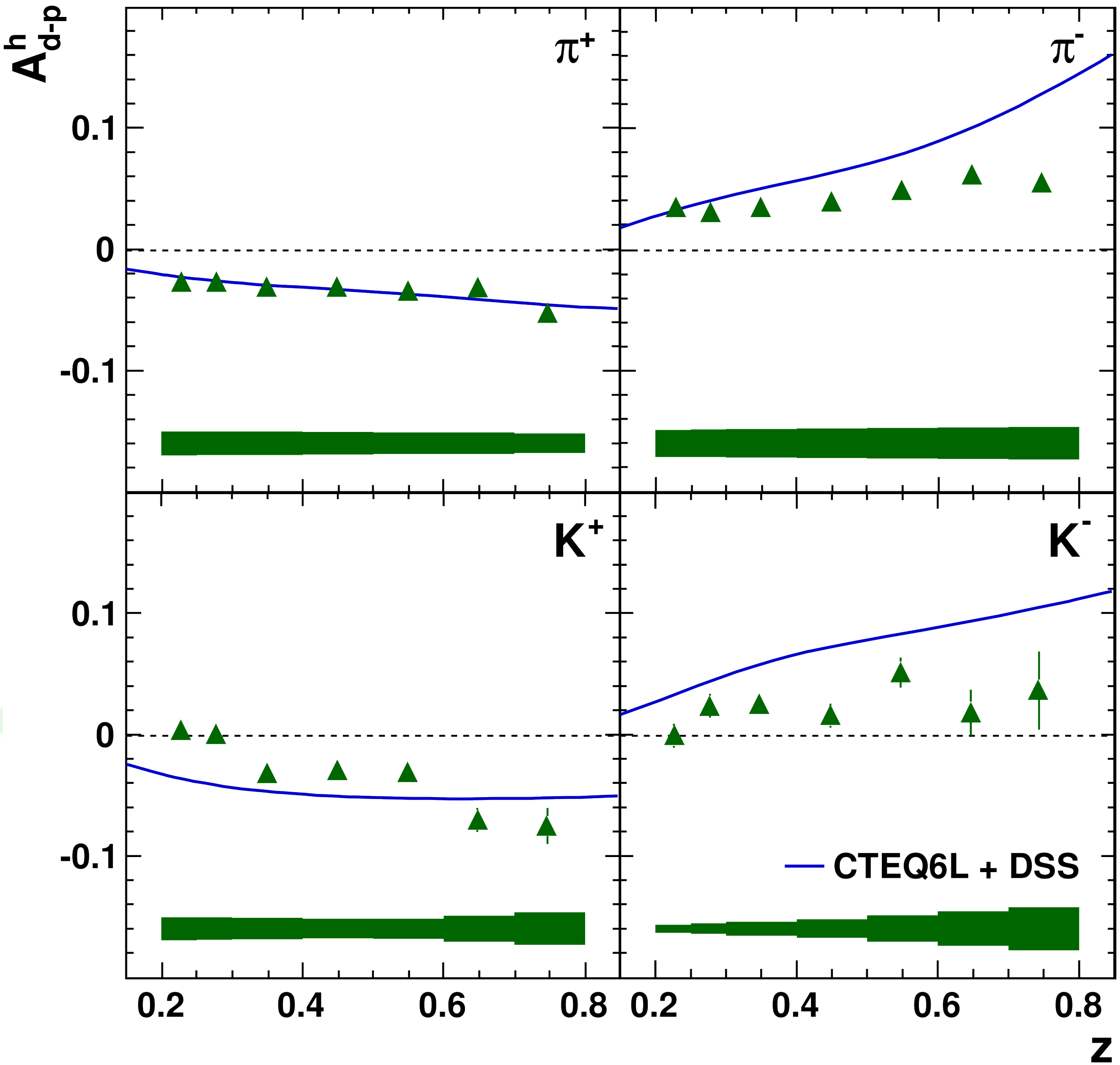
$M^h(x_B, Q^2, z, P_{h\perp})$





$M^h(x_B, Q^2, z, P_{h\perp})$

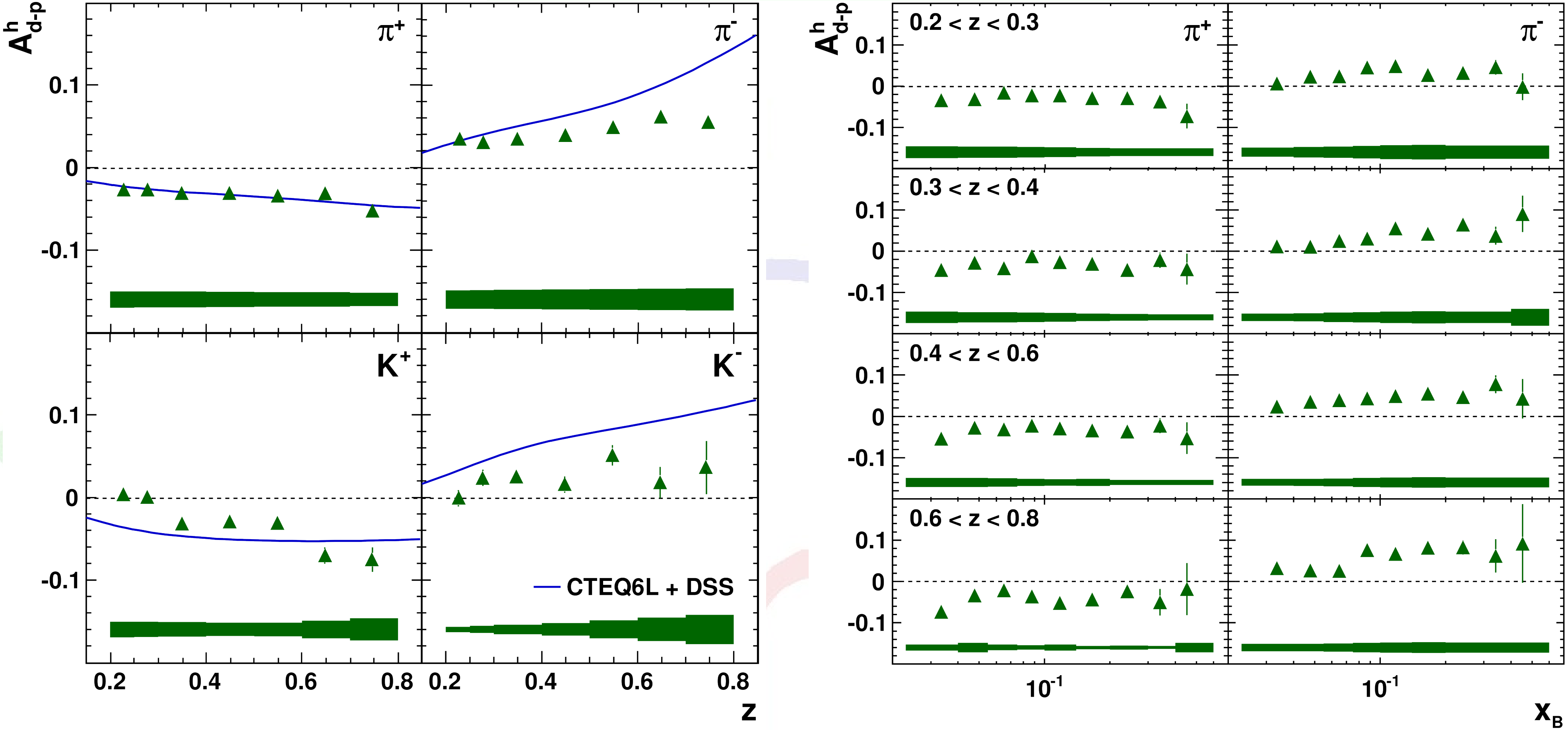




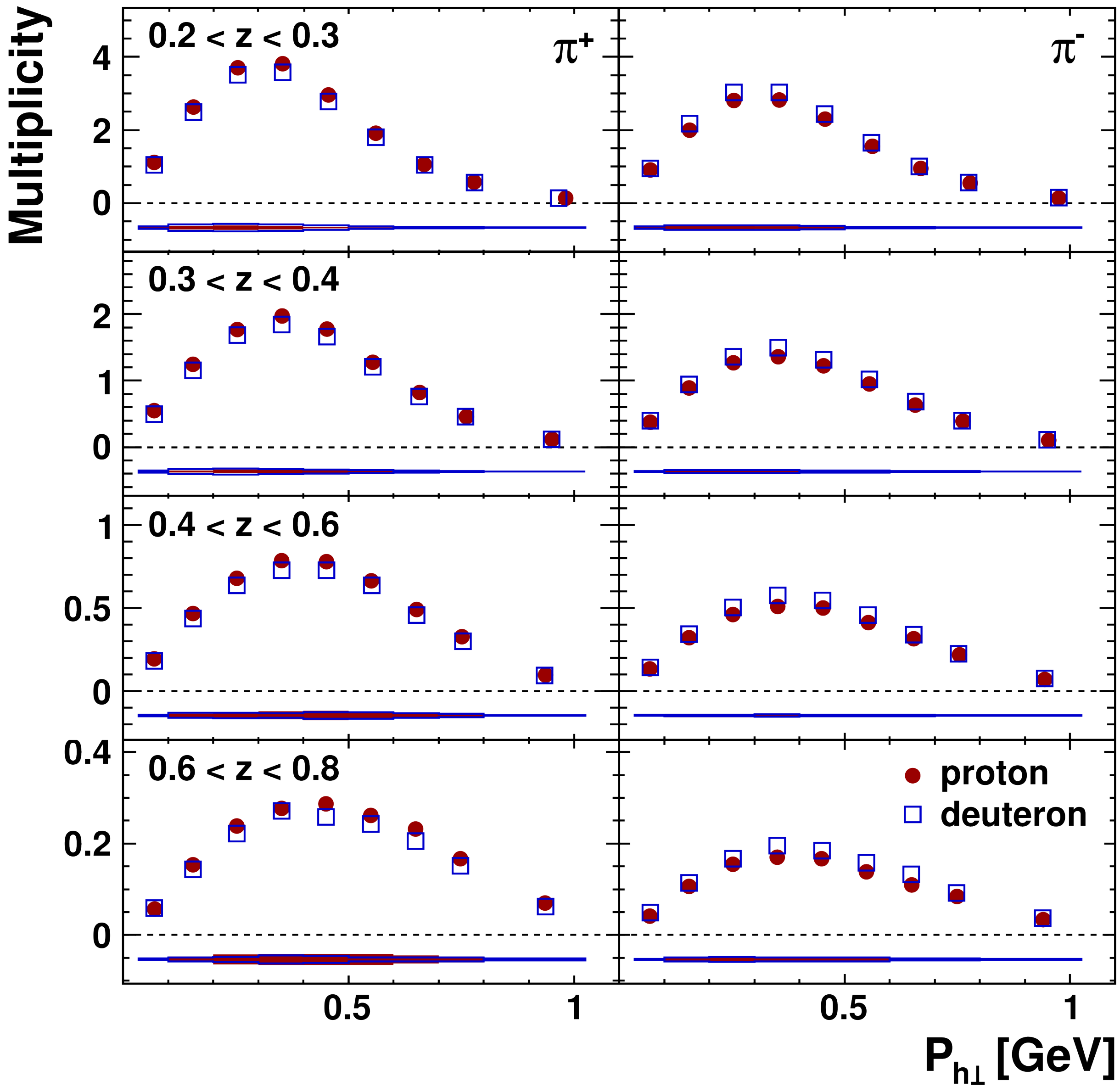
$$A^h_{d-p} = \frac{M^h_{deuteron} - M^h_{proton}}{M^h_{deuteron} + M^h_{proton}}$$

- Small magnitudes for asymmetries($M^h_p \approx M^h_n$).
- A sign of the asymmetries reflects favored/unfavored fragmentation for different hadron species on different nuclei.
- Good description of data by DSS FF's for positively charged hadrons.

$$A^{h}_{d-p} = \frac{M^{h}_{deuteron} - M^{h}_{proton}}{M^{h}_{deuteron} + M^{h}_{proton}}$$



$M^h(x_B, Q^2, z, P_{h\perp})$

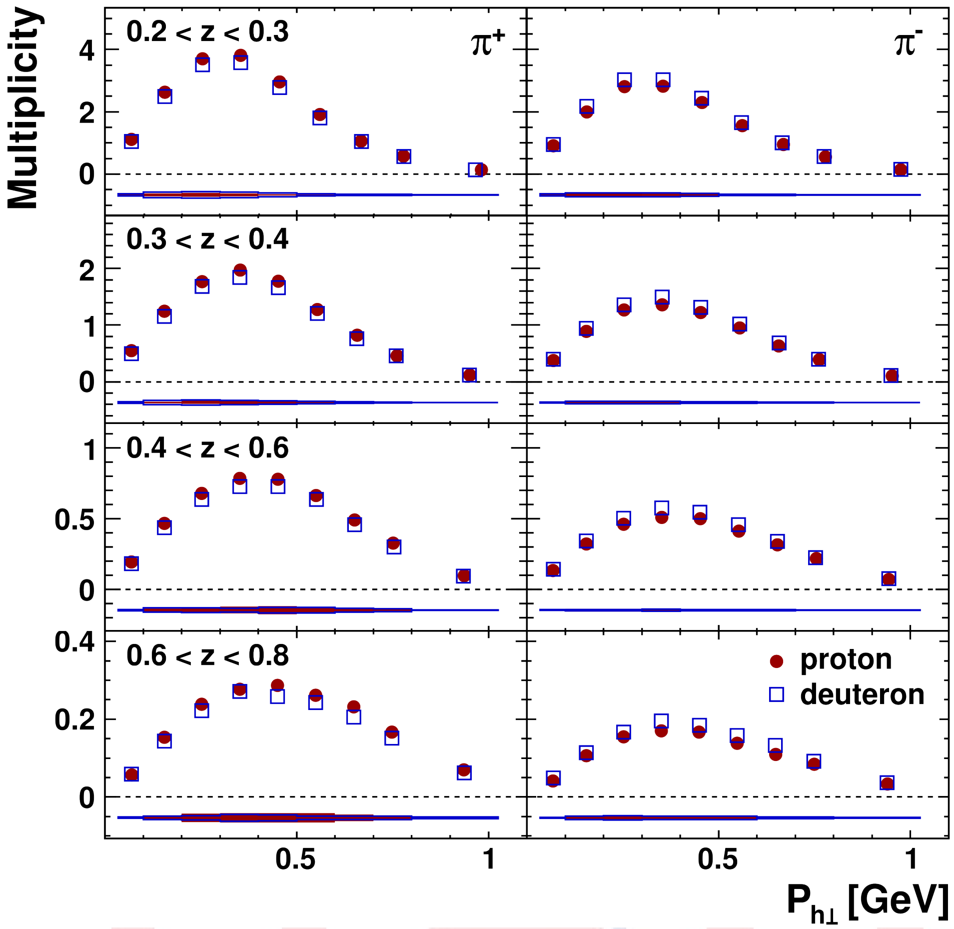


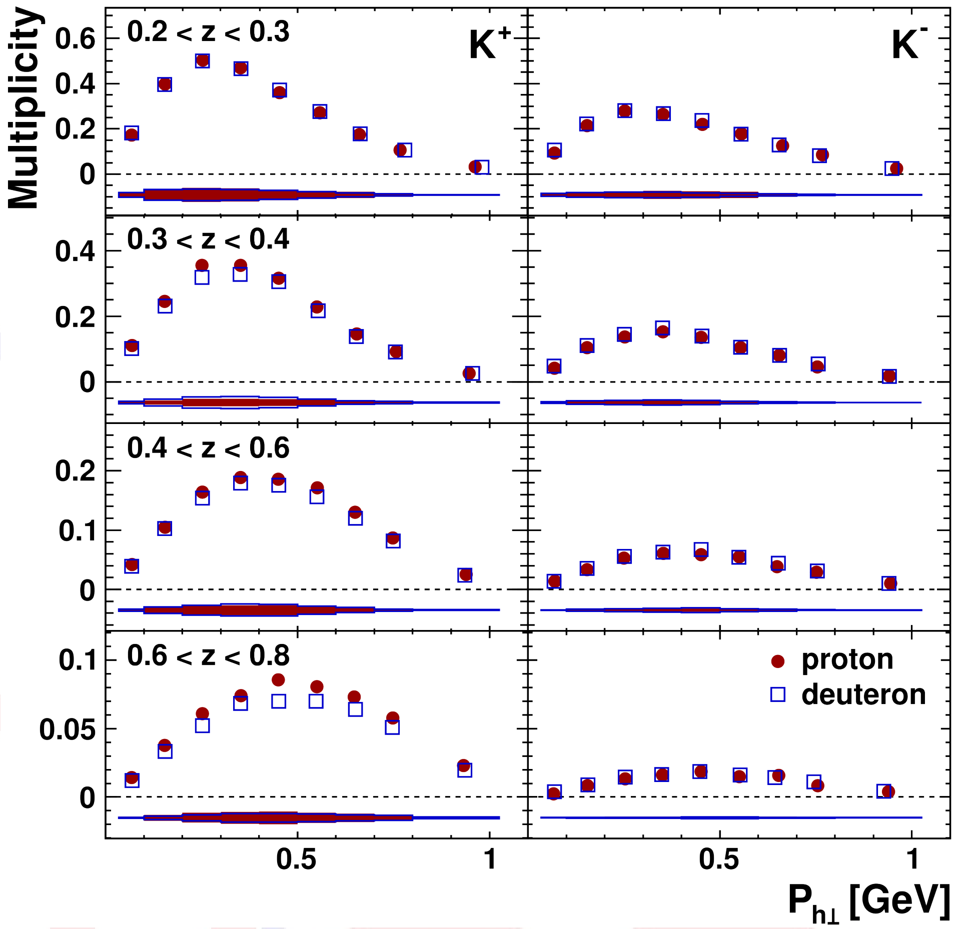
Access to the intrinsic transverse momentum of quark k_T and fragmentation p_T.

Gaussian ansatz :

$$<P^2_{h\perp}> = z^2 <k^2_T> + <p^2_T>$$

$M^h(x_B, Q^2, z, P_{h\perp})$





Summary

- High statistical data set for positively/negatively charged pion and kaon multiplicities on proton and deuteron.
- Fragmentation is favored for the hadrons containing the struck quark as a valence quark.
- Data will allow more reliable extraction of unfavored fragmentation functions.
- Dependence of multiplicities on hadron transverse momentum will provide constraints on the models of the fragmentation process.