Hadron multiplicities at the HERMES experiment
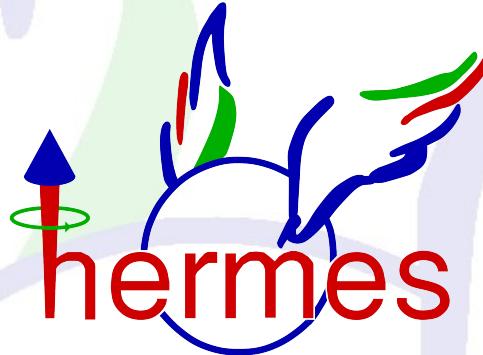
Gevorg Karyan
on behalf of the HERMES Collaboration

Alikhanyan National Science Laboratory
Yerevan, Armenia

Semi-Inclusive Deep-Inelastic Scattering

Semi-Inclusive Deep-Inelastic Scattering

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

$$\nu = E - E'$$

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

$$(E, \vec{k})$$
$$(E', \vec{k'}) \quad k'$$
$$k$$

Beam Lepton

$$q$$
$$\gamma^*$$

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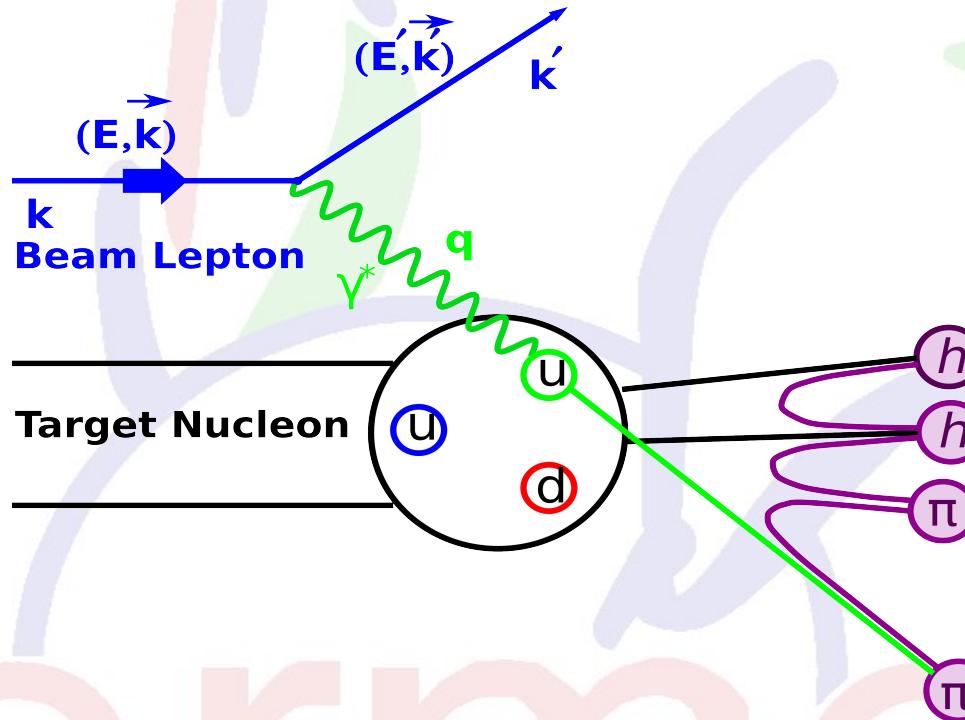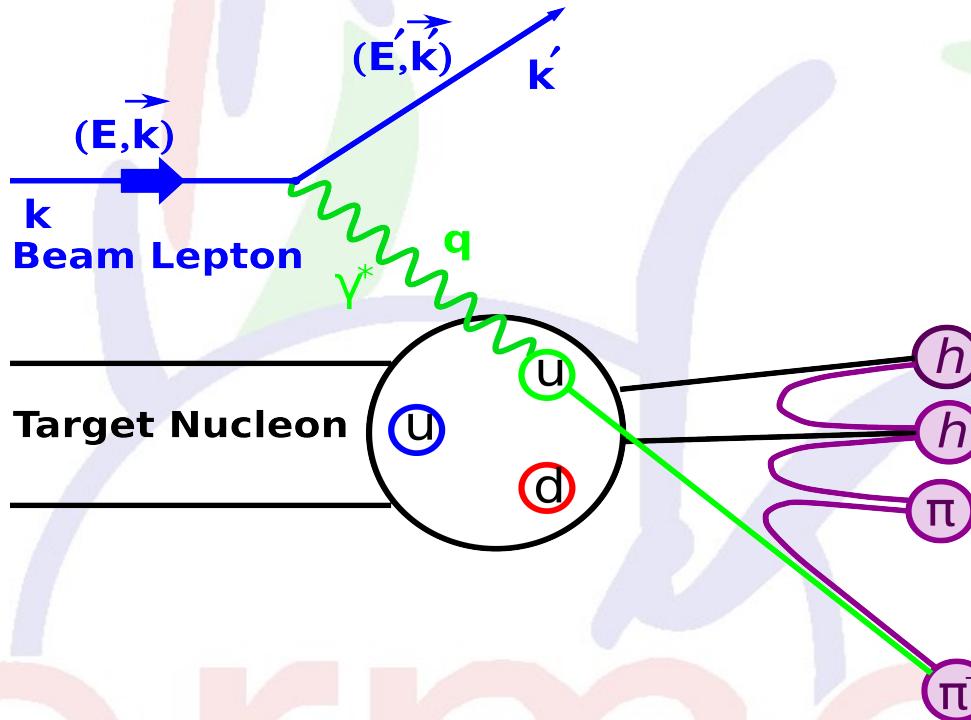
$$x_B = \frac{Q^2}{2 \cdot M_N \cdot \nu}$$

$$z = E_h / \nu$$

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

Semi-Inclusive Deep-Inelastic Scattering


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(E,$\vec{k}$) k'

(E,$\vec{k}$)
k
Beam Lepton

γ^* q

Target Nucleon

u u d

h h π π^+
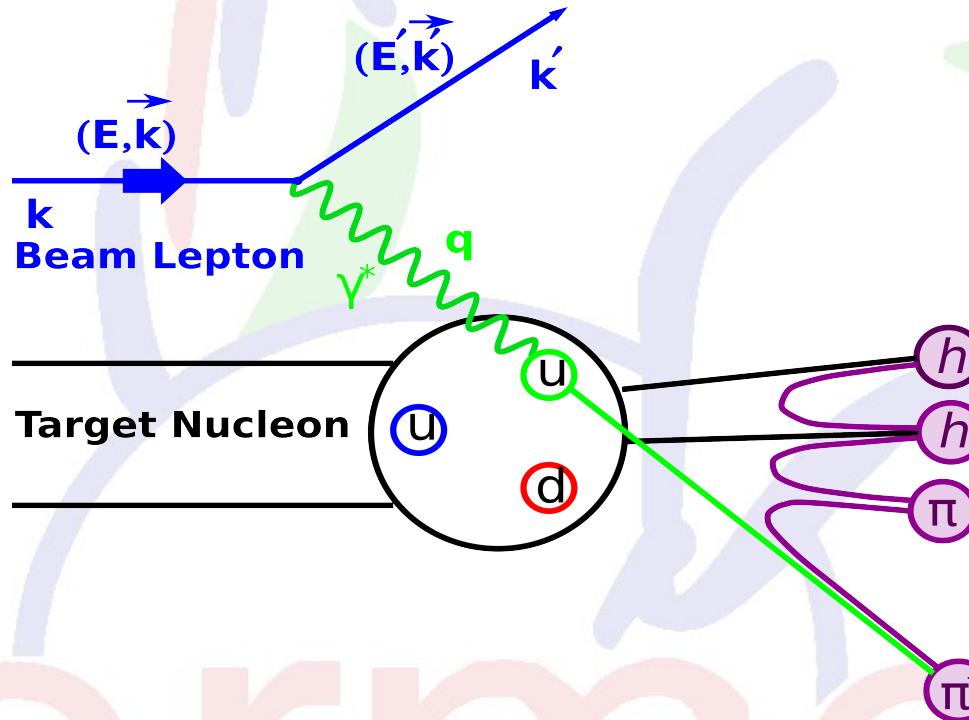
Leading Order QCD, Factorization

Semi-Inclusive Deep-Inelastic Scattering

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

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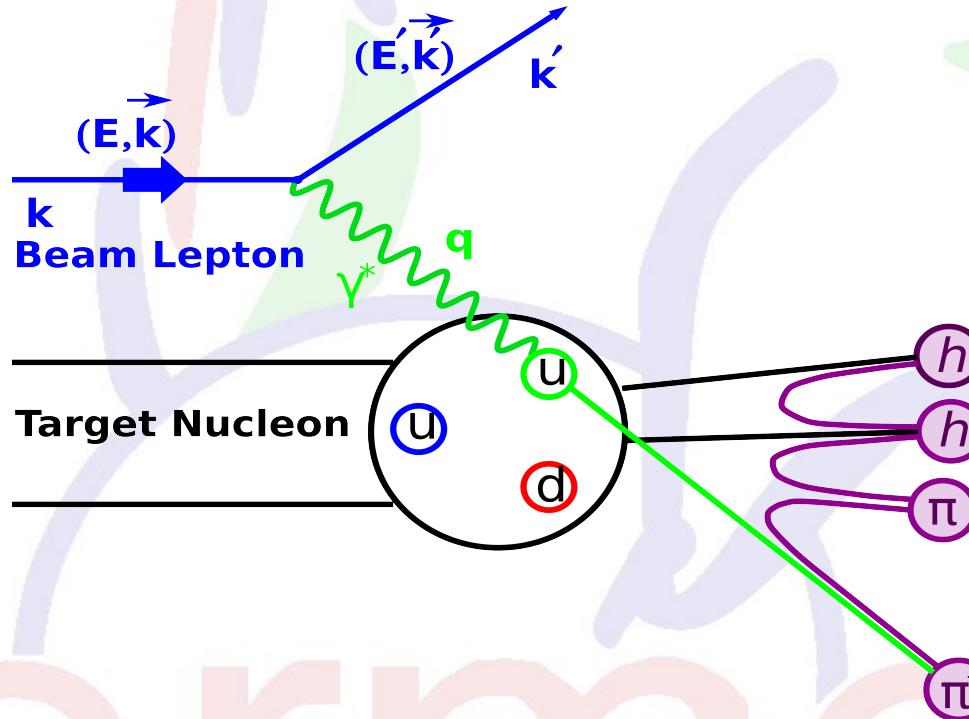
Experimental observable

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

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

Underlying physics

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

(with **PDF** highlighted over both q_f terms)

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   FF   PDF

Underlying physics

Collinear Framework

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

PDFs are well known   **FFs are poorly known**

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

PDFs are well known

FFs are poorly known

Particularly unfavored FFs

Underlying physics

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

CTEQ6L, GRV, ...   **DSS, Kretzer, ...**

Universality

SIDIS(e+N), SIA(e⁺+e⁻), HS(p+p)
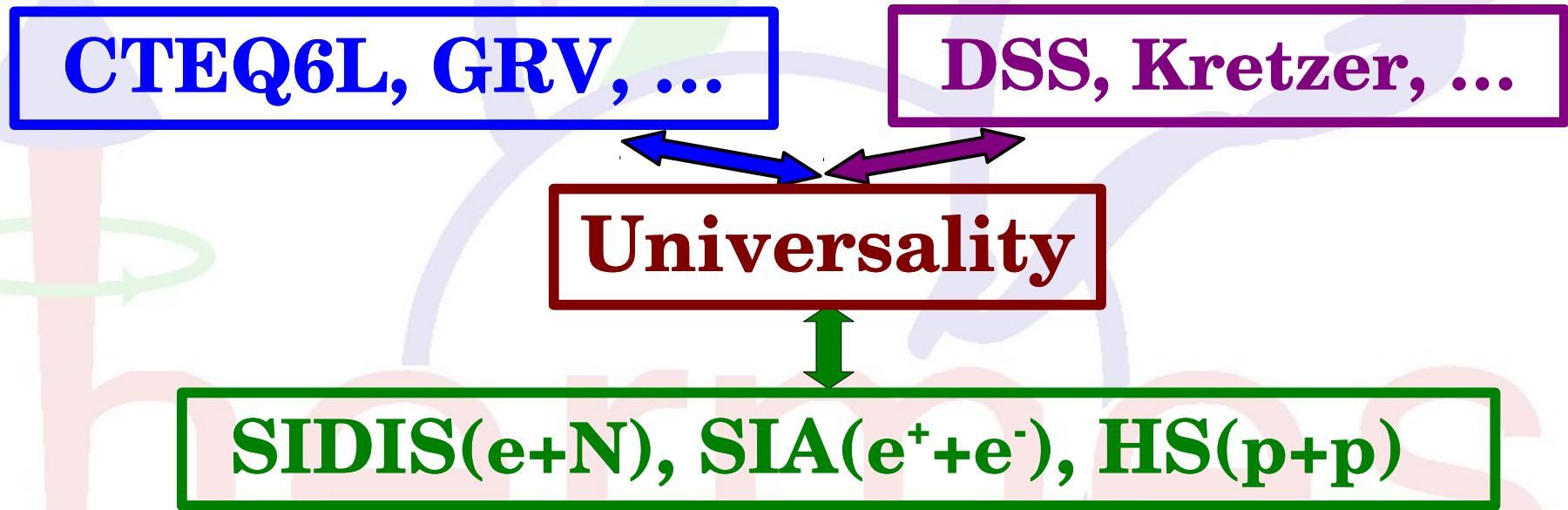
Advantage of SIDIS

Charge separated FFs

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

SIDIS

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

Flavour separated FFs

Experiment
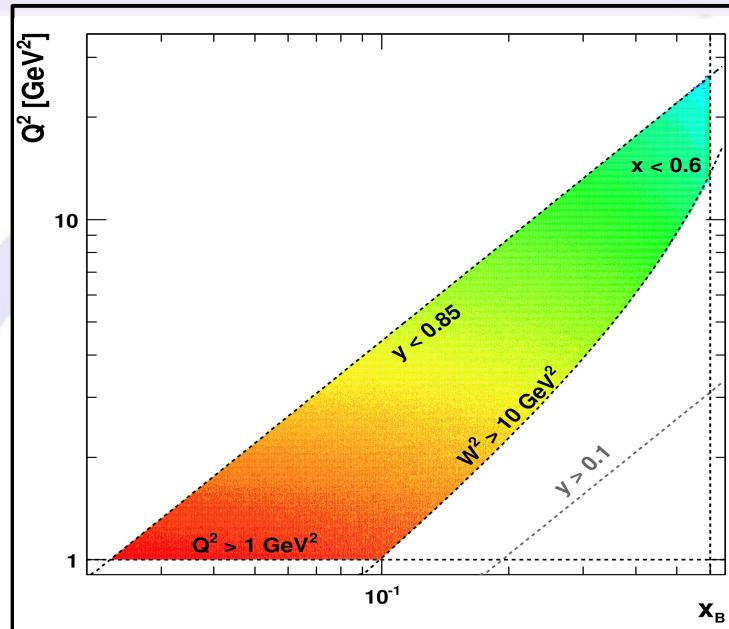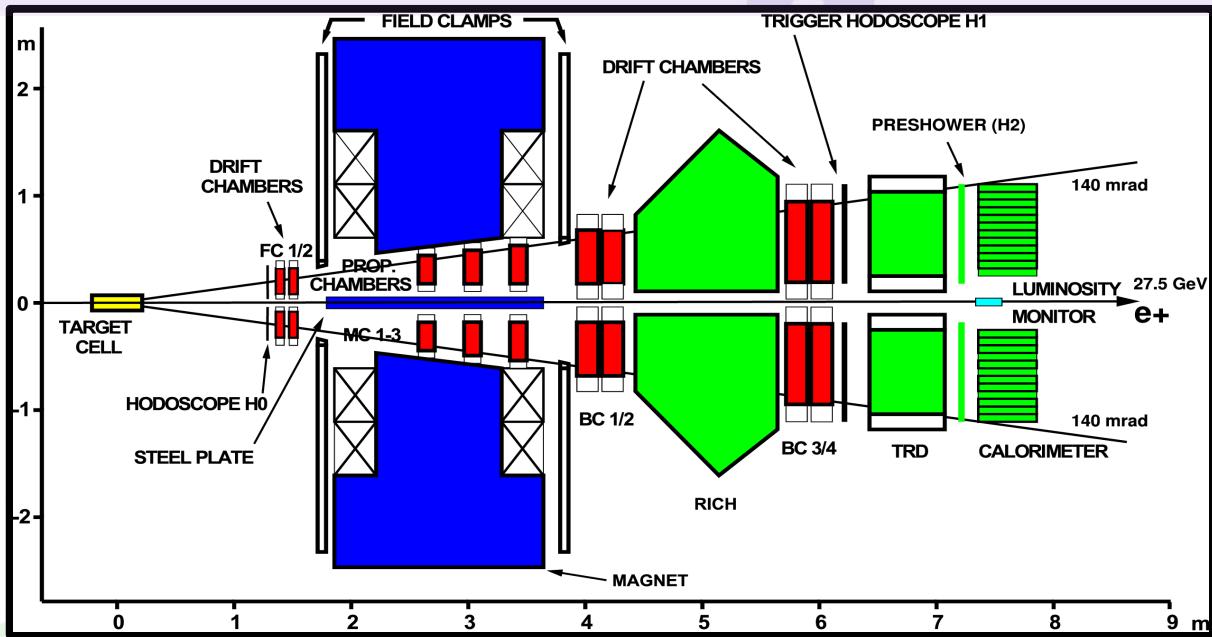
Beam : e⁻/e⁺ 27.6 GeV

Target : H/D pure gaseous

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

Excellent particle identification

Experiment
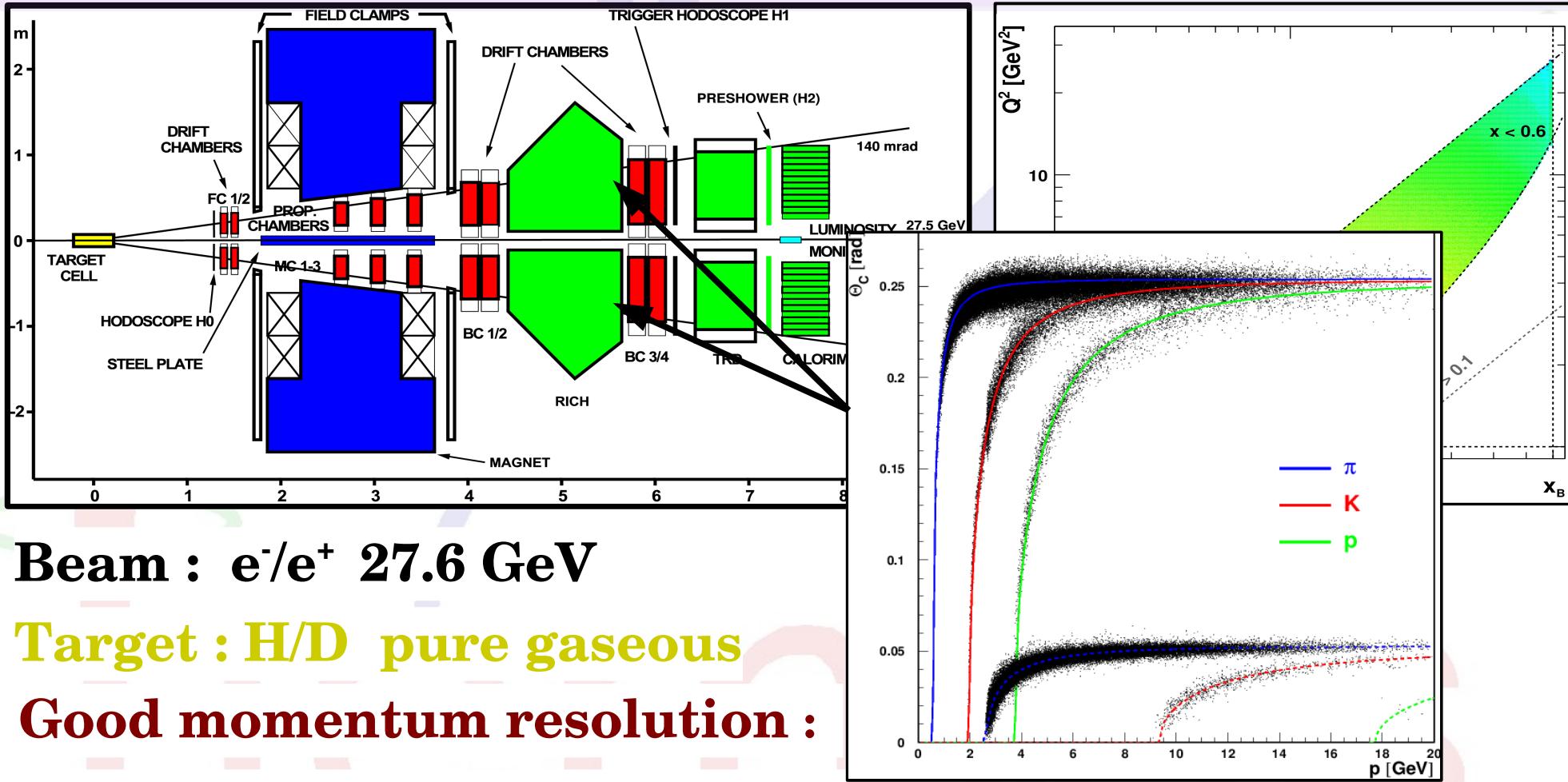
Beam : e⁻/e⁺ 27.6 GeV

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, $\gamma \rightarrow e^+e^-$**)

RICH Unfolding

Trigger Efficiencies

Diffractive Vector Meson Contribution

Detector Smearing & QED Radiative Effects

Final Data

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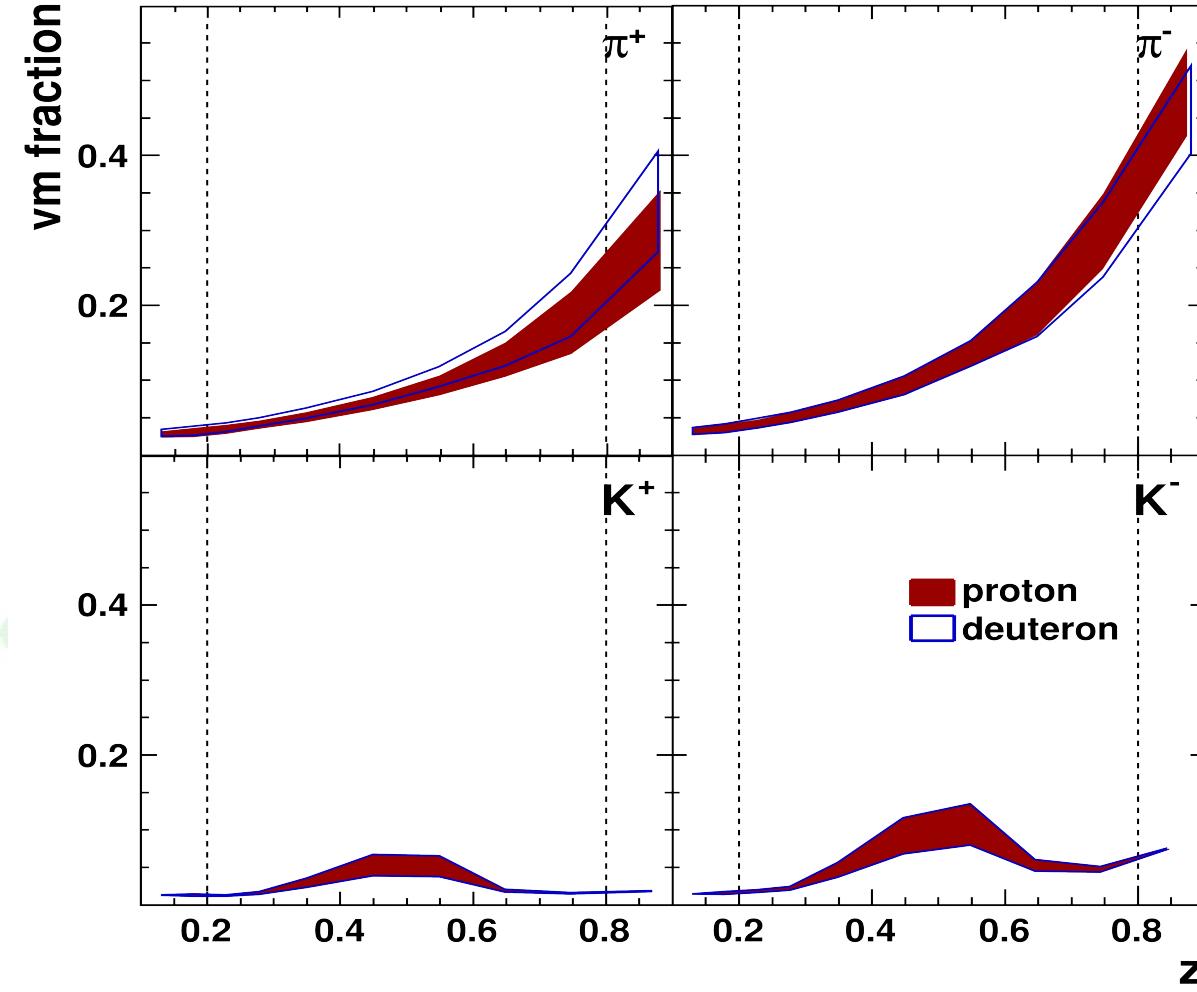
Due to diffractively produced exclusive $\rho^0 \to \pi^+\pi^-$ and $\phi \to K^+K^-$

➢ **Results with and without VM substraction.**

Results

arXiv:1212.5407v1
A. Airapetian et. al, Phys. Rev. D (2013)(accepted)

➢ **In this presentation results are with VM substraction.**

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

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

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

proton $\rightarrow$ 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**

$$M^{K^-}_{deuteron} \simeq M^{K^-}_{proton}$$
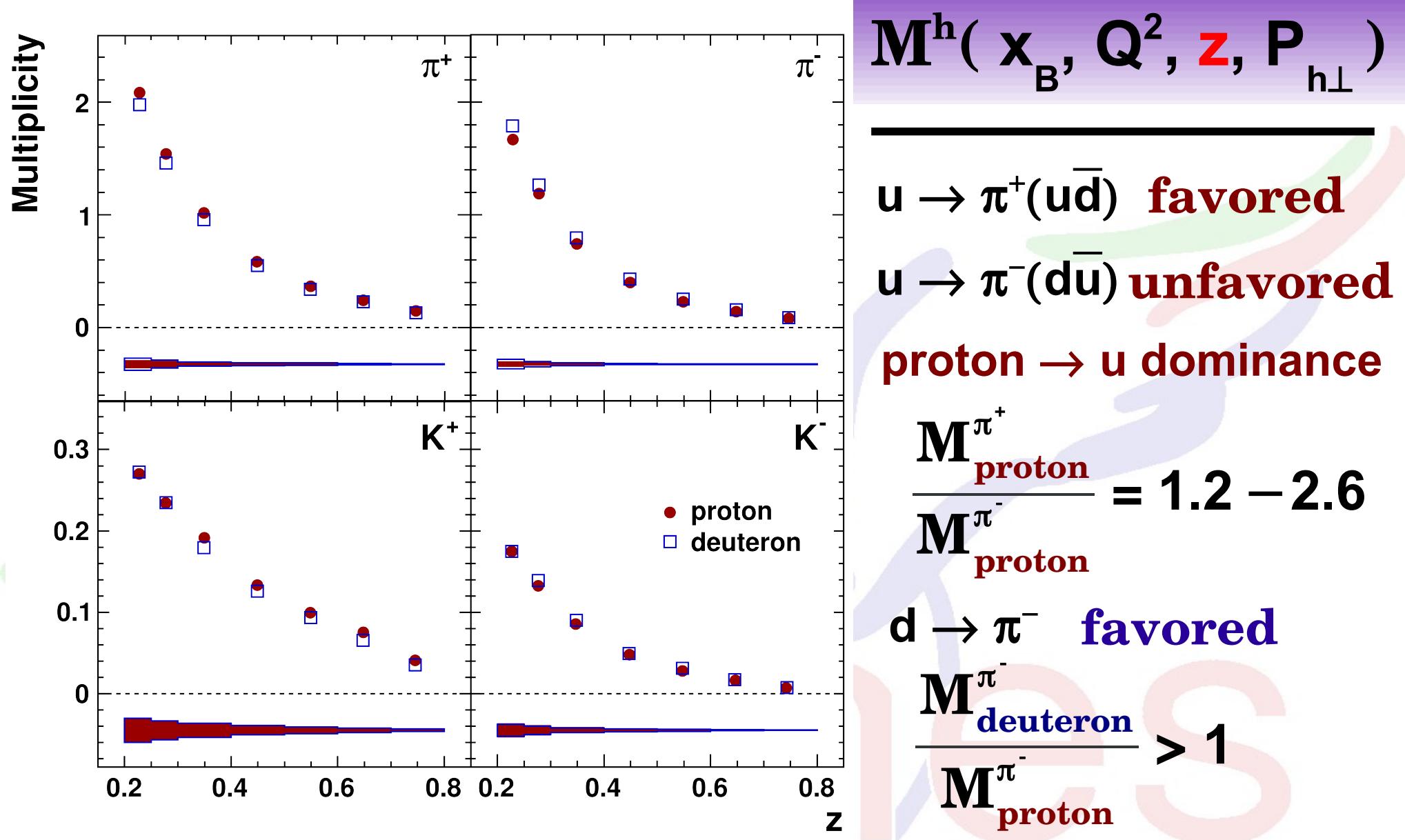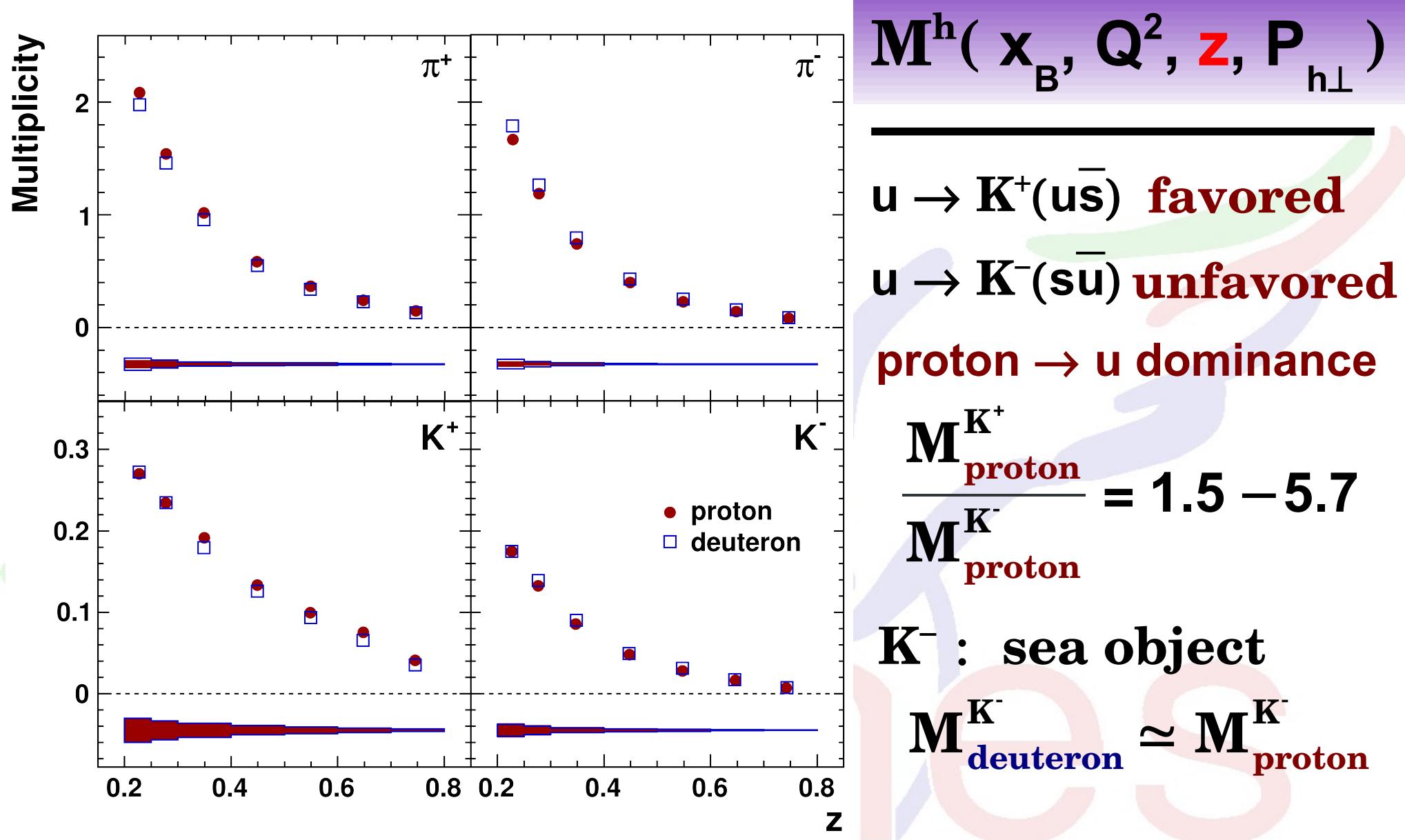
$$M^h(\ x_B,\ Q^2,\ z,\ P_{h\perp}\ )$$

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.**
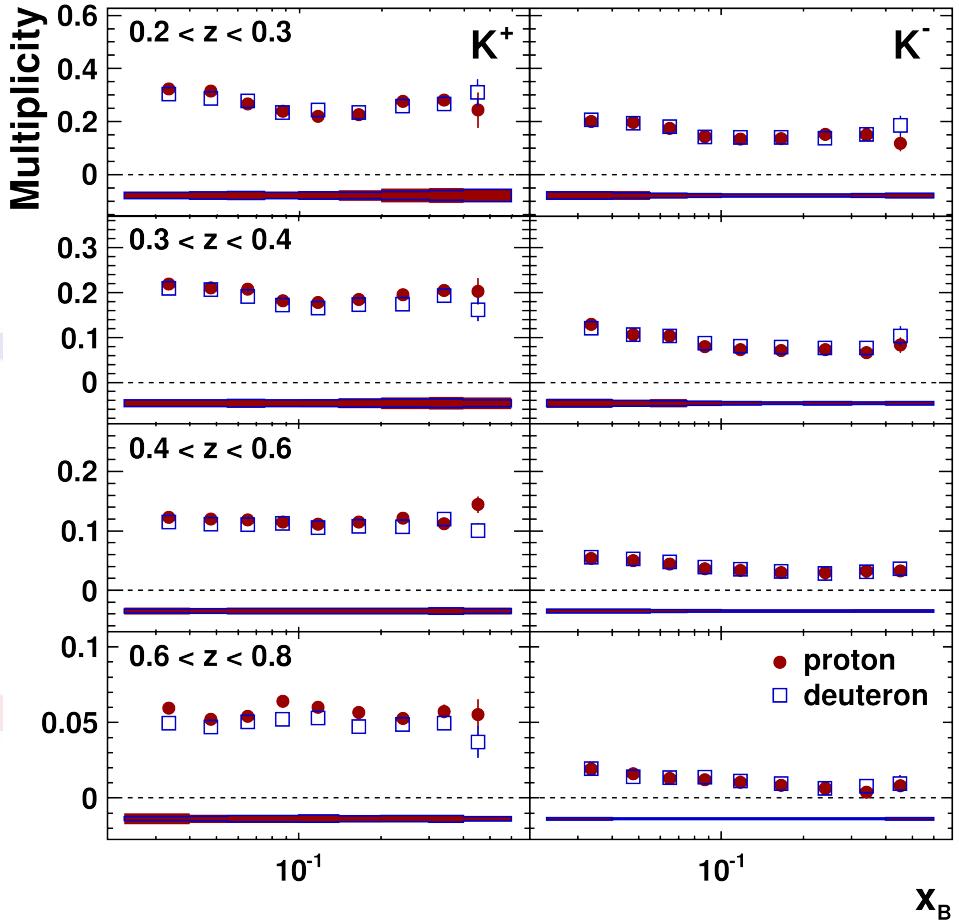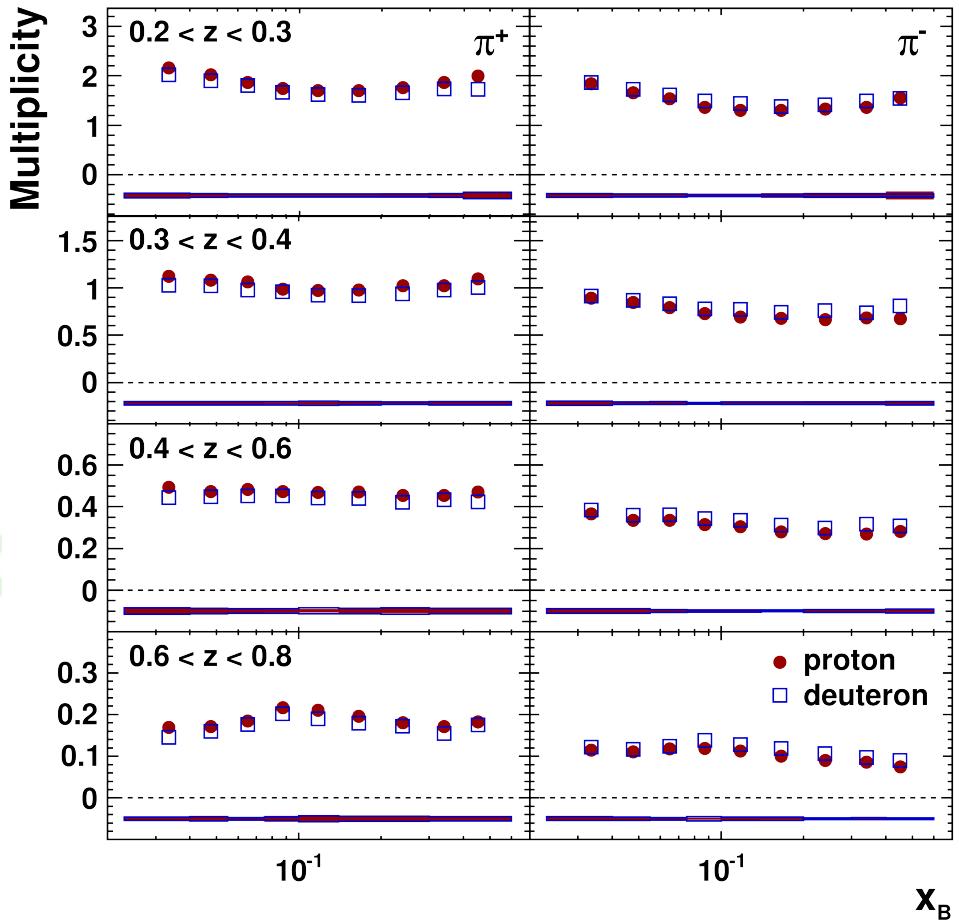
Legend (bottom center panel):
- proton
- CTEQ6L/DSS
- CTEQ6L/HKNS
- CTEQ6L/Kretzer
- HERMES LEPTO/JETSET

Panel labels: π^+, π^-, K^+, K^-

Y-axis: Multiplicity; X-axis: z

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

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.
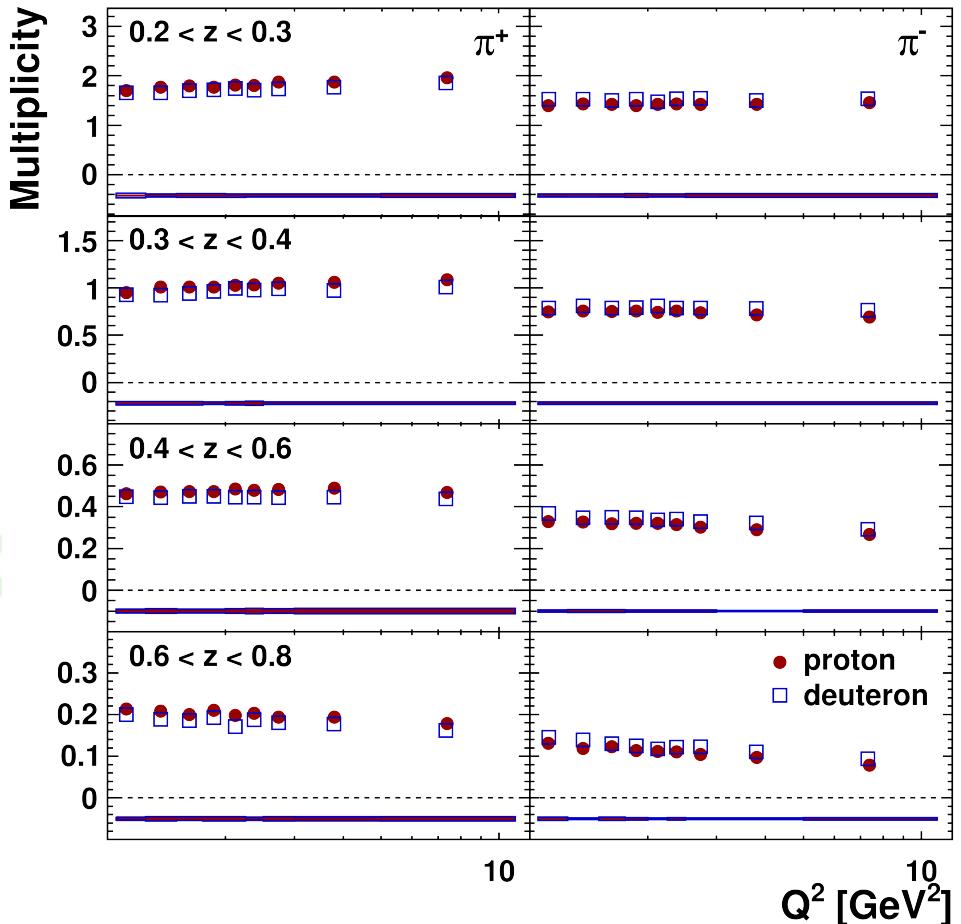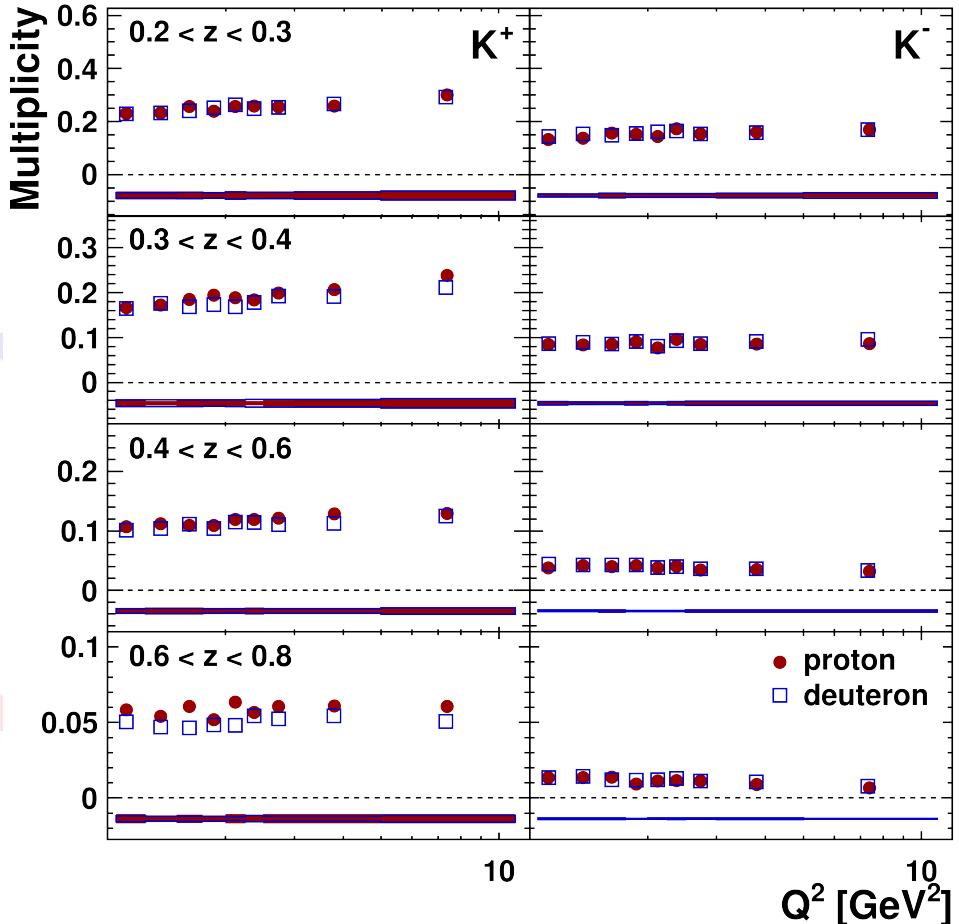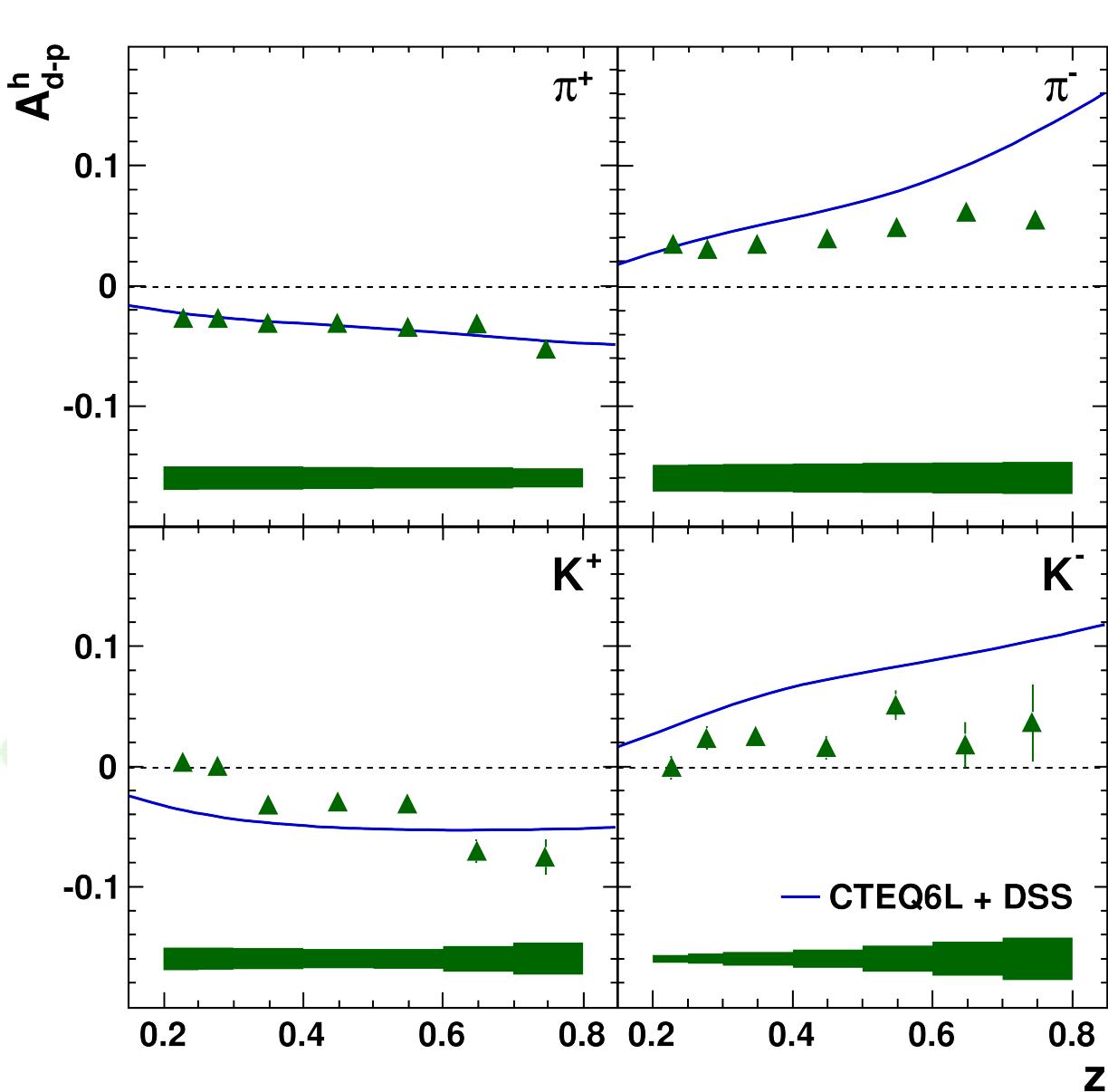
$$A_{d-p}^{h} = \frac{M_{deuteron}^{h} - M_{proton}^{h}}{M_{deuteron}^{h} + M_{proton}^{h}}$$

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

...beyond the collinear factorization.
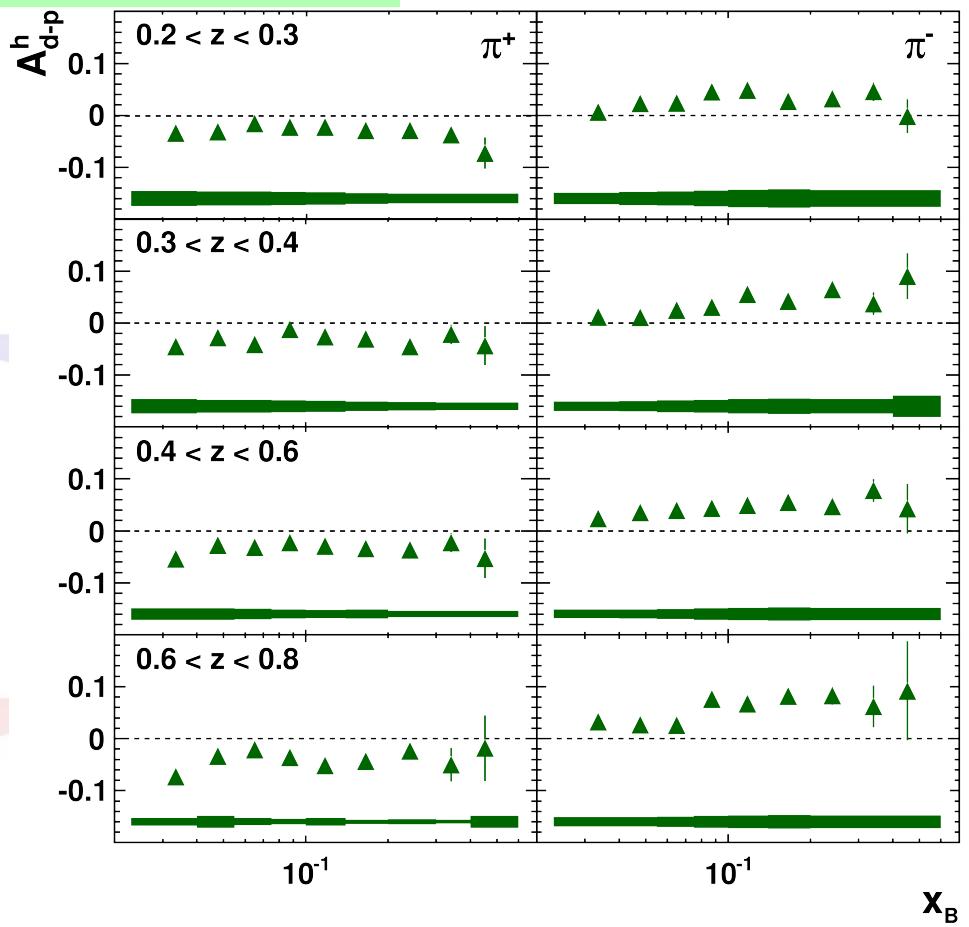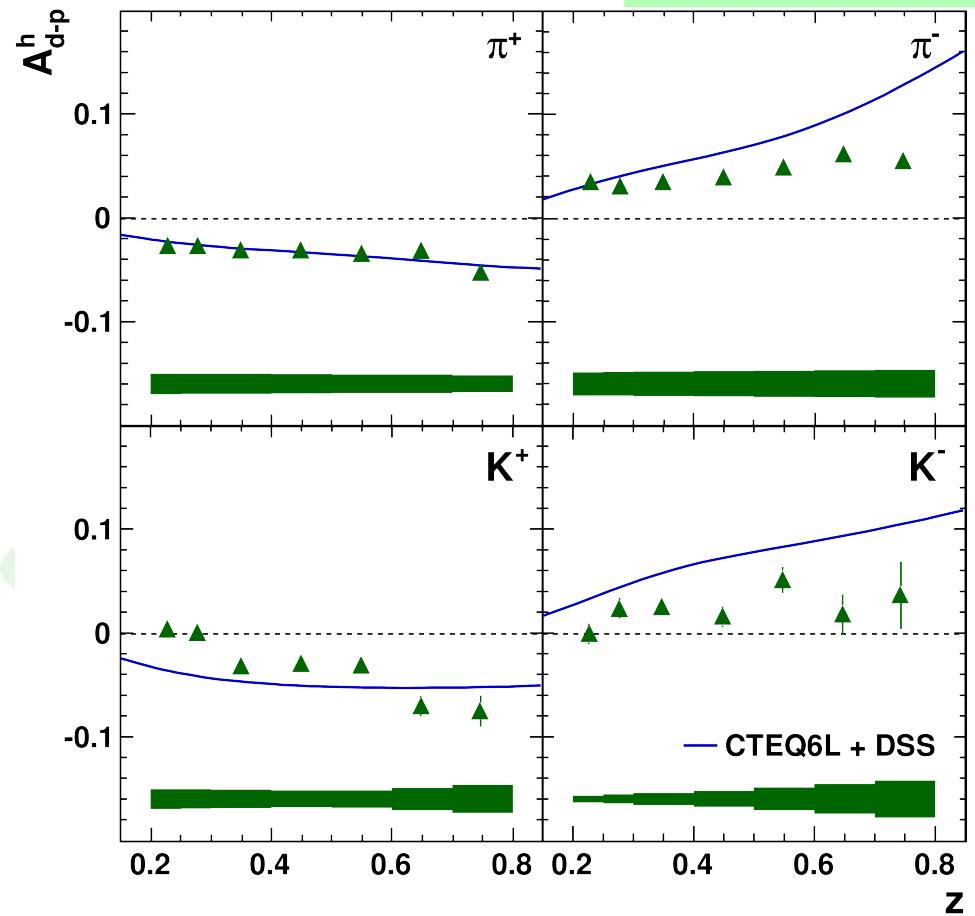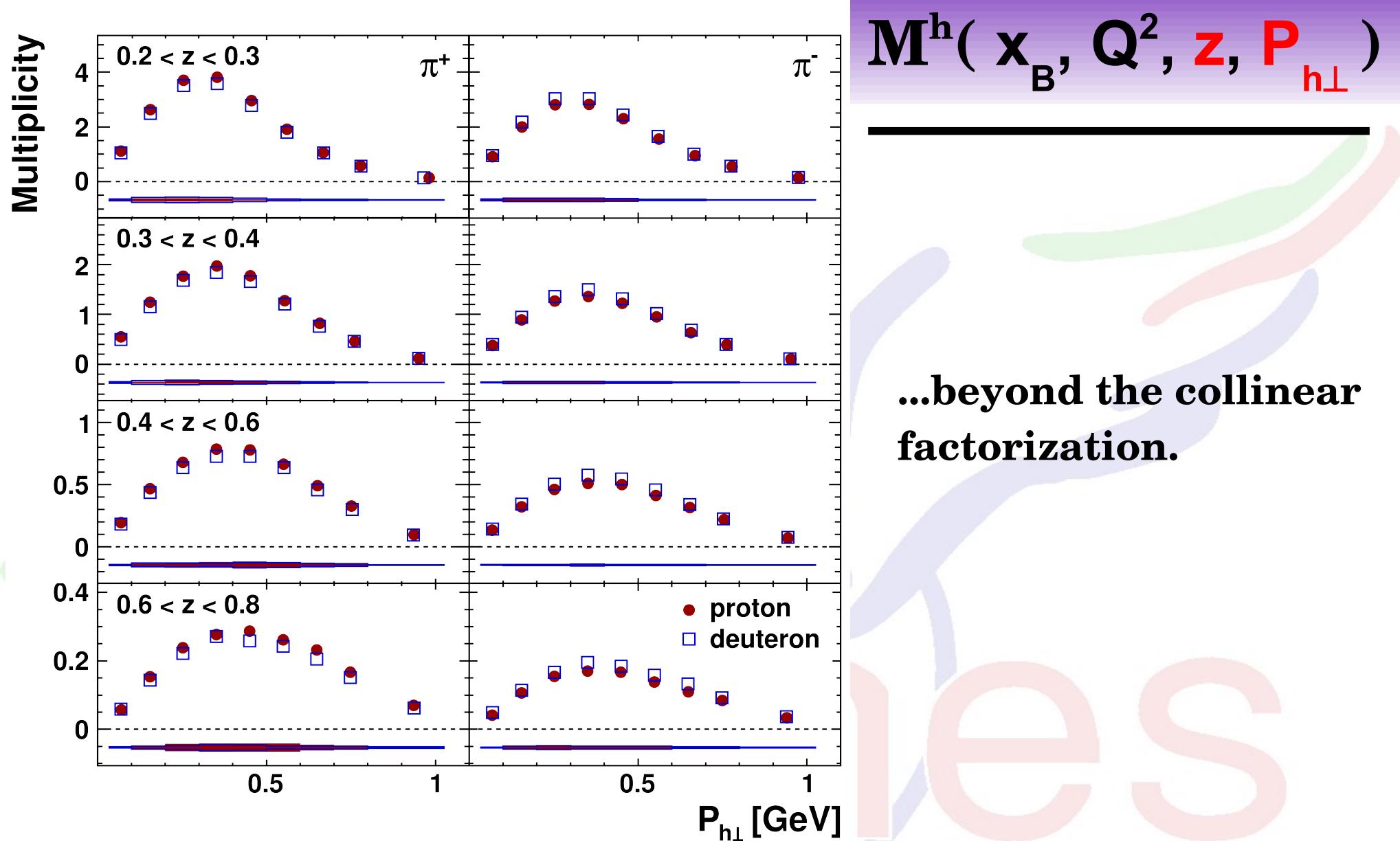
$$M^h(x_B, Q^2, z, P_{h\perp})$$
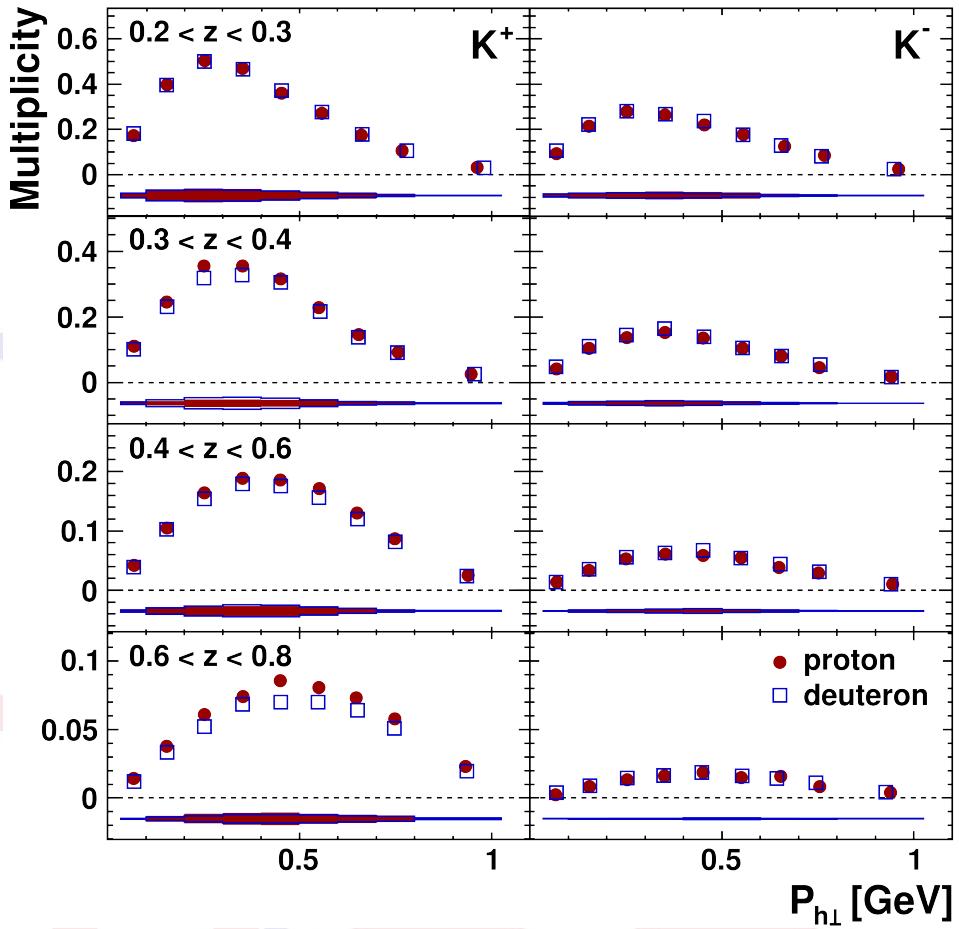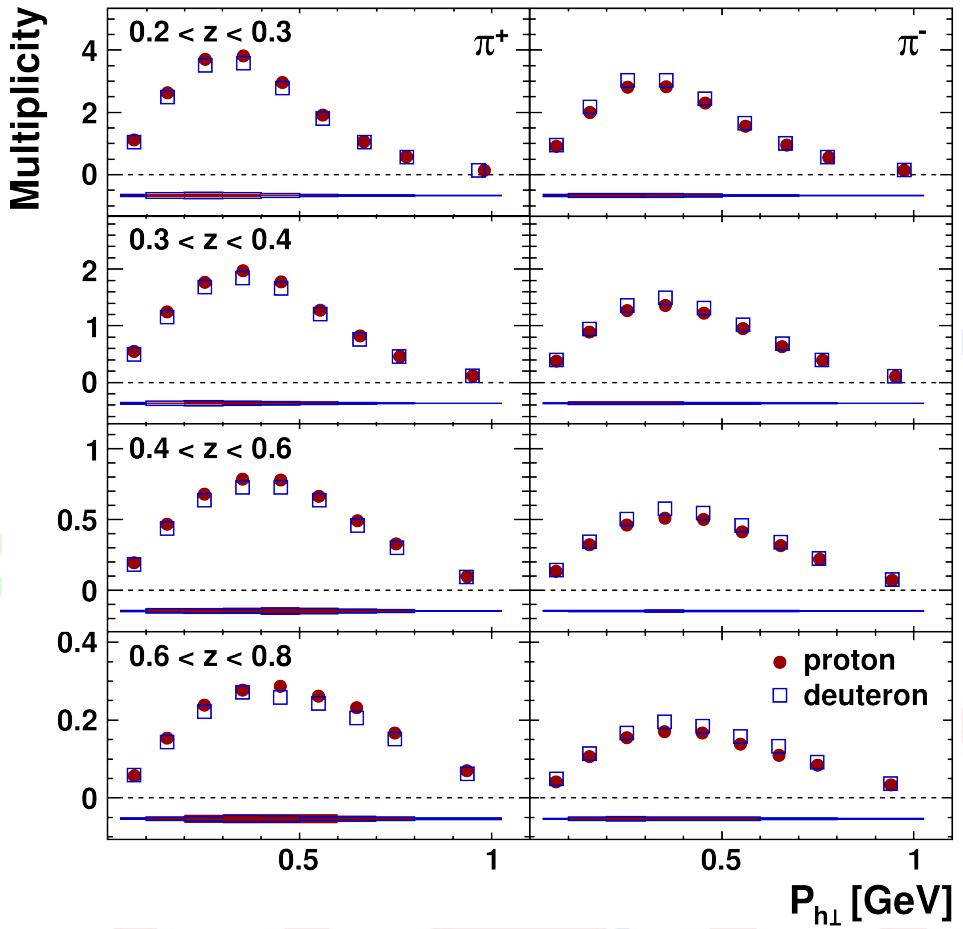
Summary

➢ **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.**