Multiplicities of charged pions and kaons and the strange quark distribution in the nucleon at HERMES

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on behalf of the HERMES Collaboration

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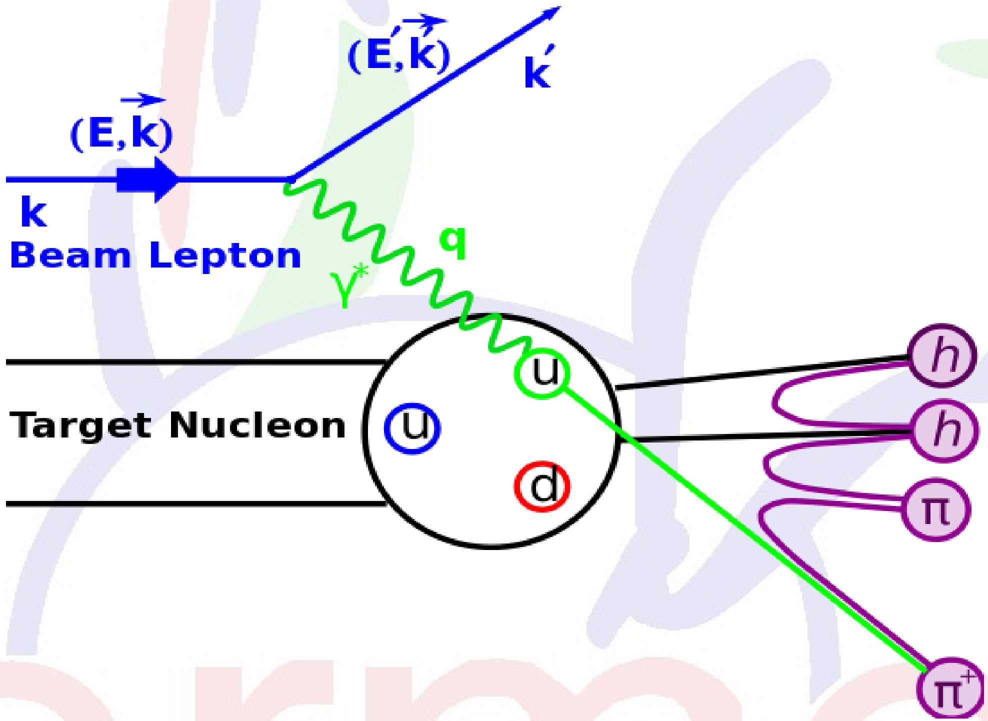
Semi-Inclusive Deep-Inelastic Scattering

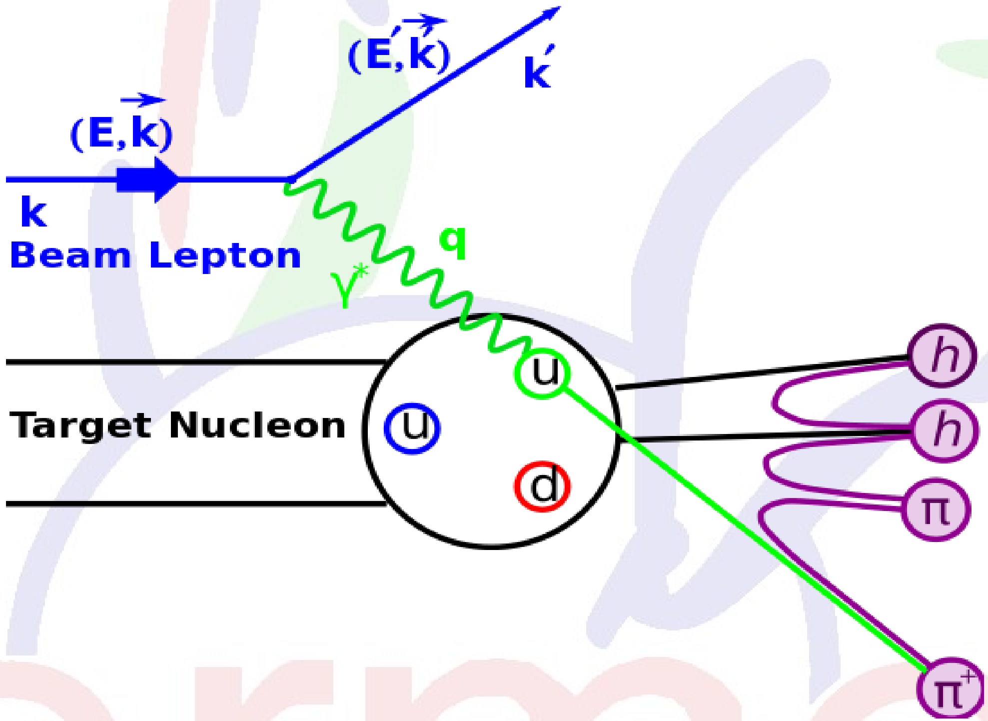


Semi-Inclusive Deep-Inelastic Scattering

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

$$\nu = E - E'$$

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



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

$$z = E_h / \nu$$

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

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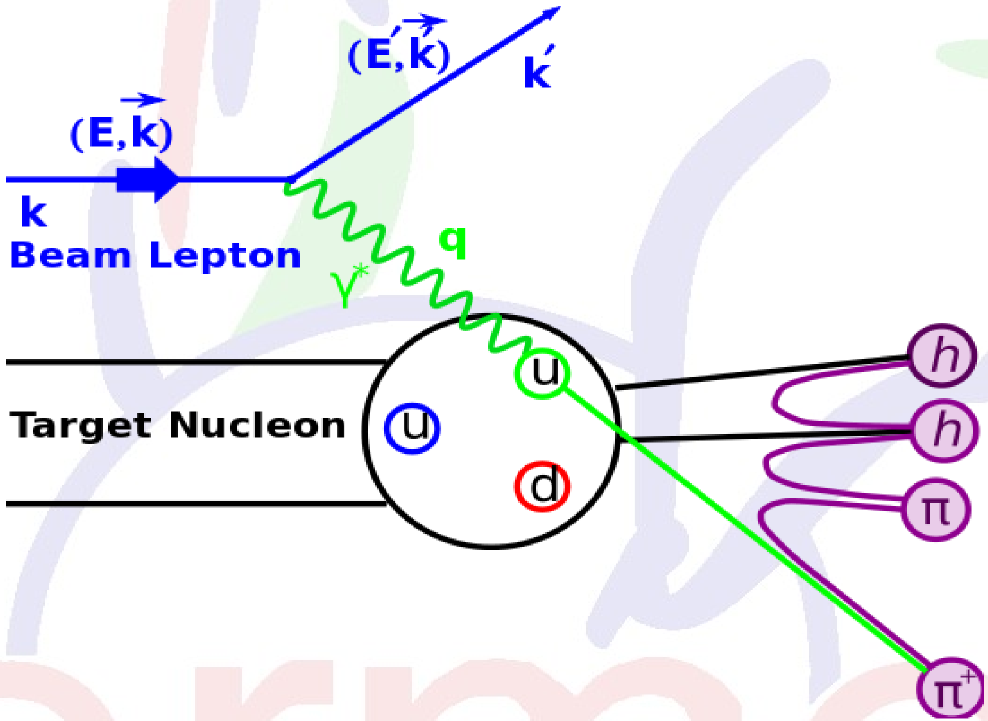

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TMD factorization at leading order in $(k_\perp / Q)$, $P_{h\perp} \simeq k_\perp \ll Q$

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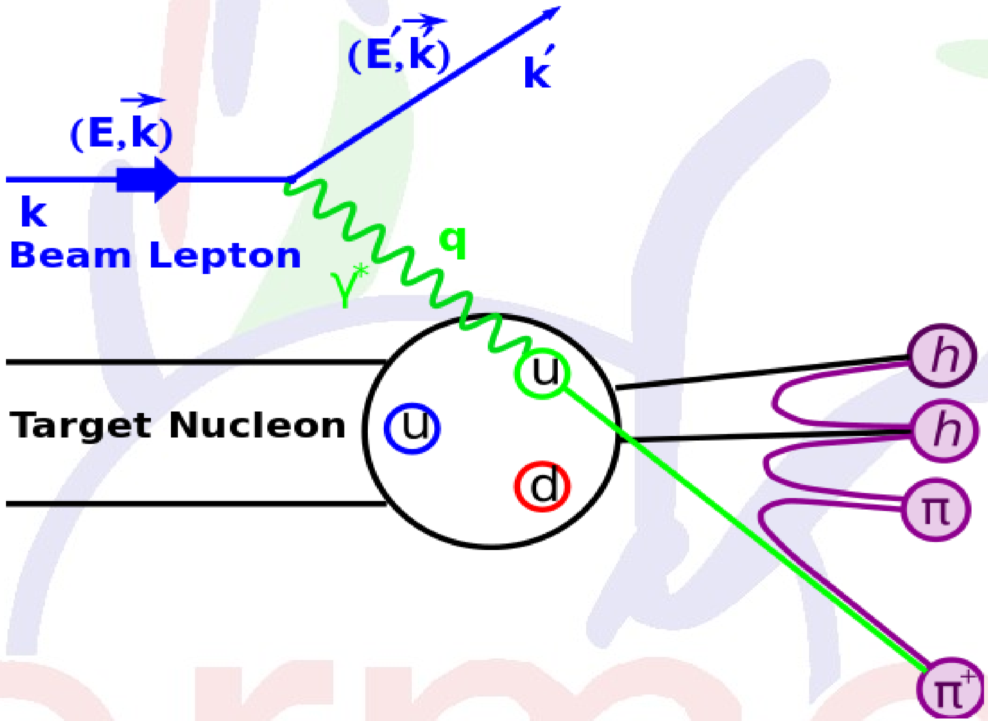

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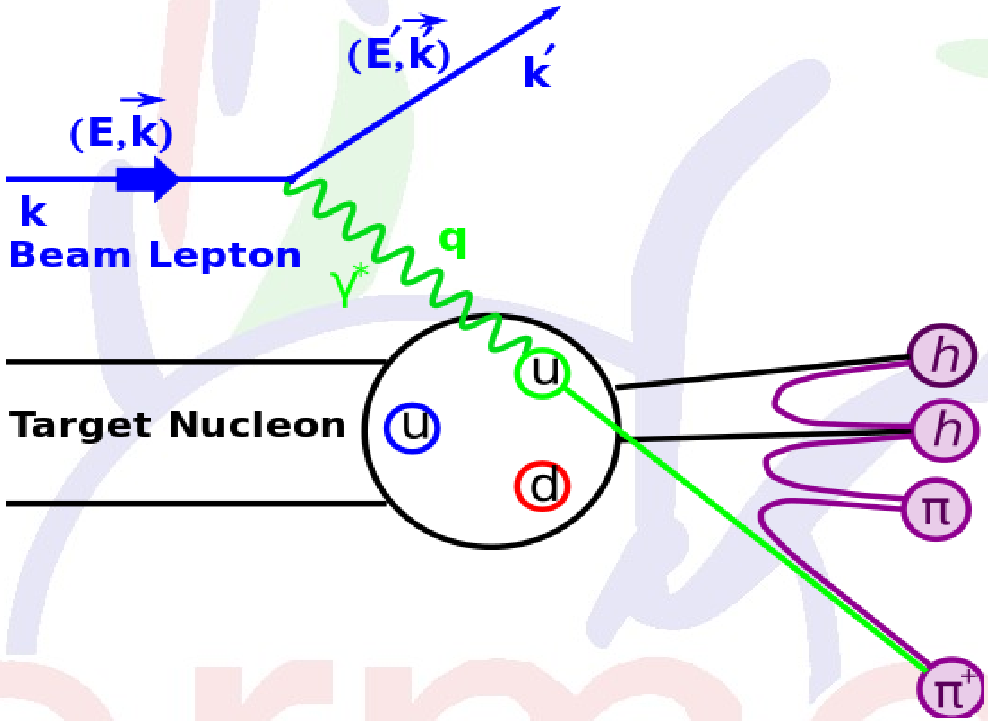

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TMD-PDF TMD-FF

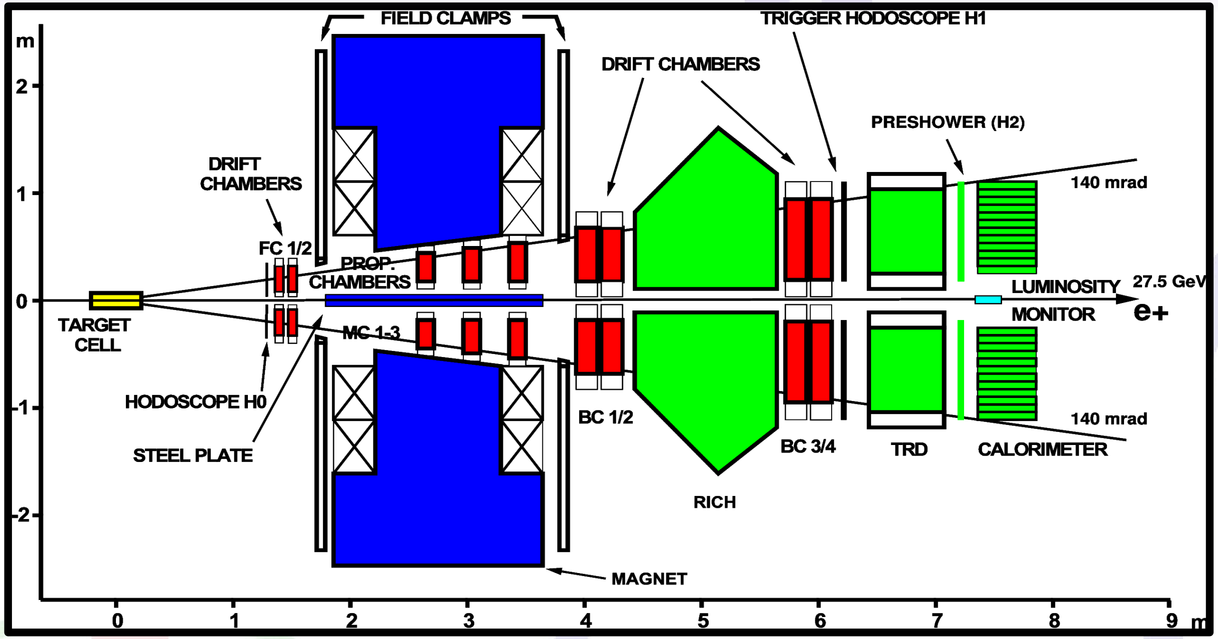
Experimental observable

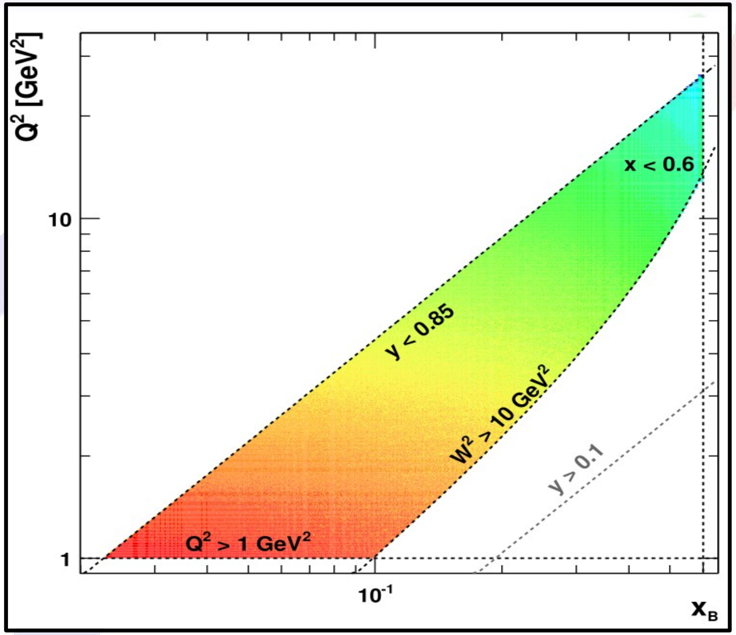
SIDIS hadron yields

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

DIS event yields

Experiment





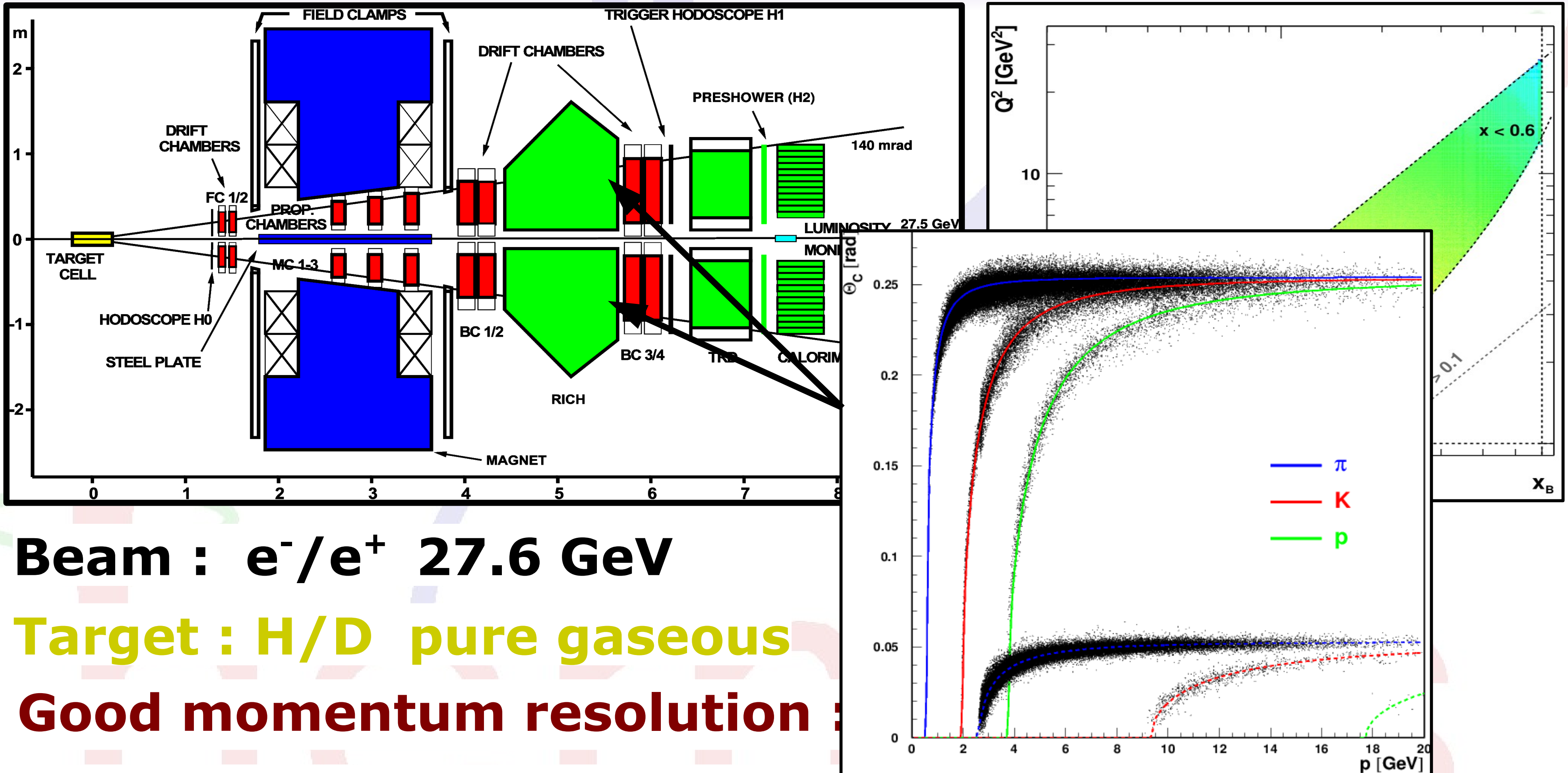
Beam : e^-/e^+ 27.6 GeV

Target : H/D pure gaseous

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

Excellent particle identification

Experiment



Beam : e^-/e^+ 27.6 GeV

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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

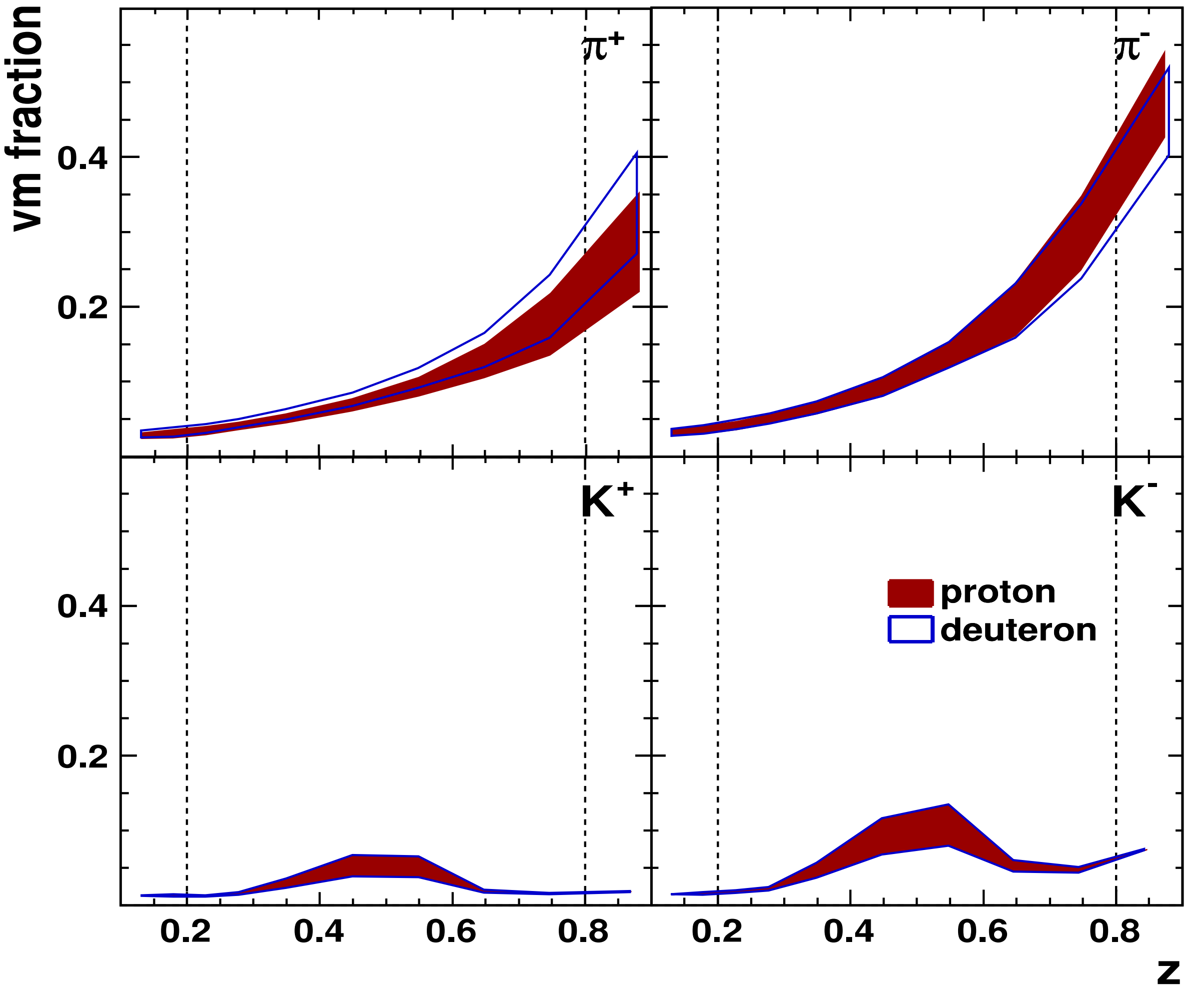
Trigger Efficiencies

Diffractive Vector Meson Contribution

Detector Smearing & QED Radiative Effects

Final Data

Diffractive vector meson contribution



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

- **Results with and without VM subtraction.**

Experimental observable

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

DIS event yields

Experimental observable

SIDIS hadron yields

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

Collinear framework

DIS event yields

Underlying physics

Collinear framework

$$M^h \sim \frac{\sum_q e_q^2 \, \underbrace{f_q(x_B, Q^2)}_{\text{PDF}} \, \underbrace{D_q^h(z, Q^2)}_{\text{FF}}}{\sum_q e_q^2 \, \underbrace{f_q(x_B, Q^2)}_{\text{PDF}}}$$

using collinear PDFs (well known)

extract collinear FFs

Underlying physics

$$M^h \sim \frac{\sum_q e_q^2 f_q(x_B,Q^2) D_q^h(z,Q^2)}{\sum_q e_q^2 f_q(x_B,Q^2)}$$

PDF FF

PDF

CTEQ6L, GRV, ...

DSS, Kretzer, ...

Universality

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

Advantage of SIDIS

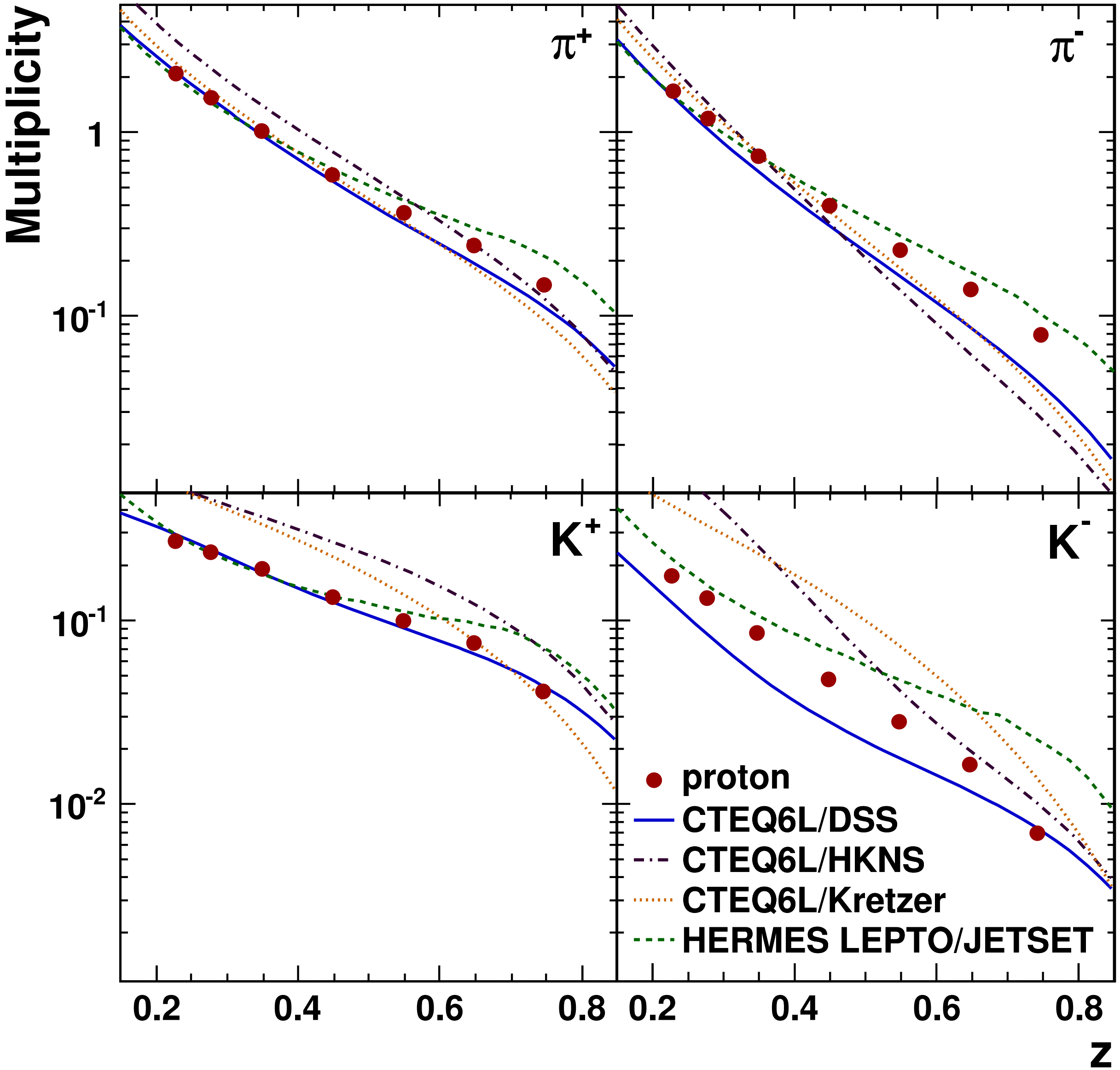
Charge separated FFs

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

SIDIS

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

Flavor separated FFs



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

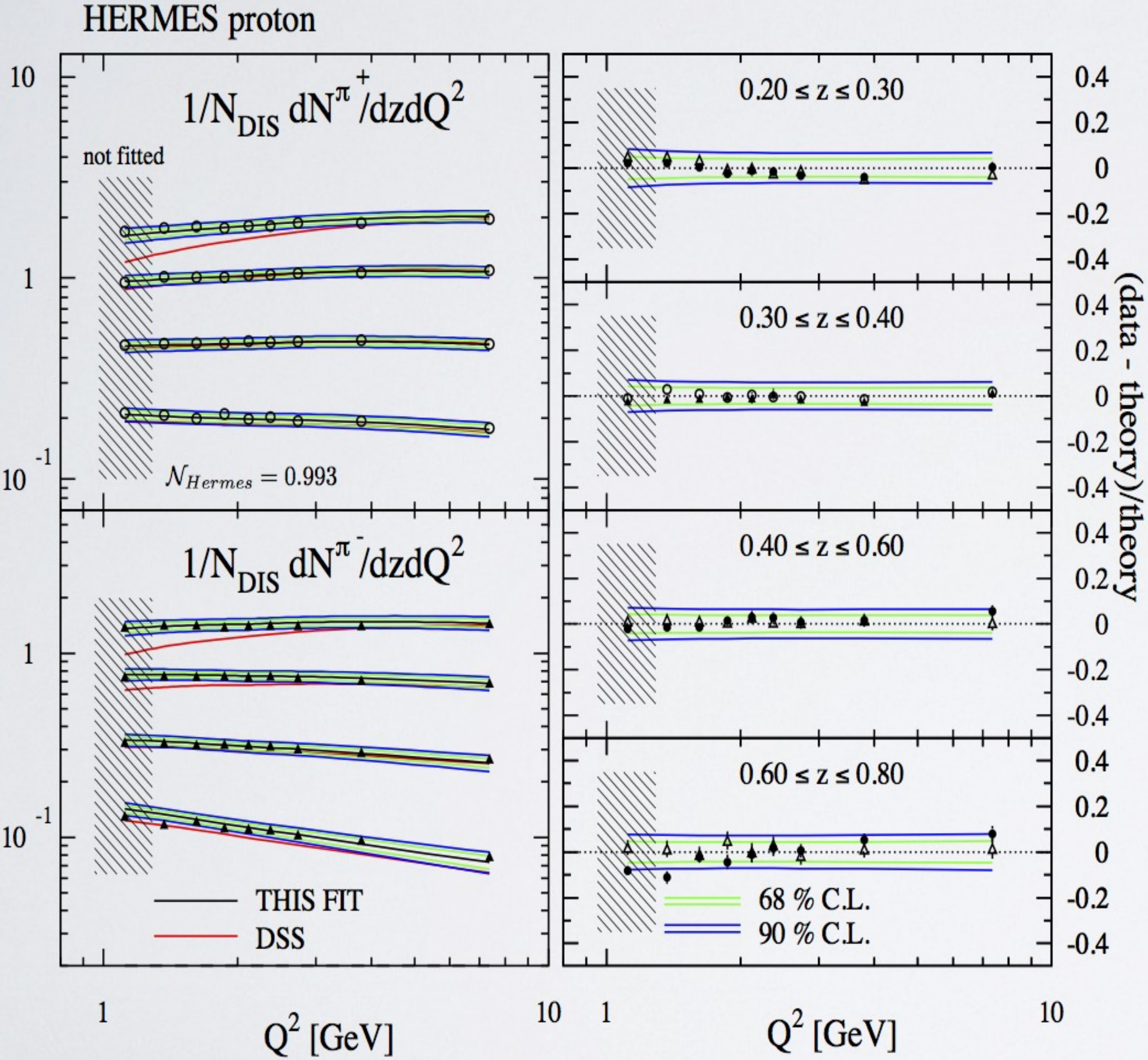
Proton target

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.**

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



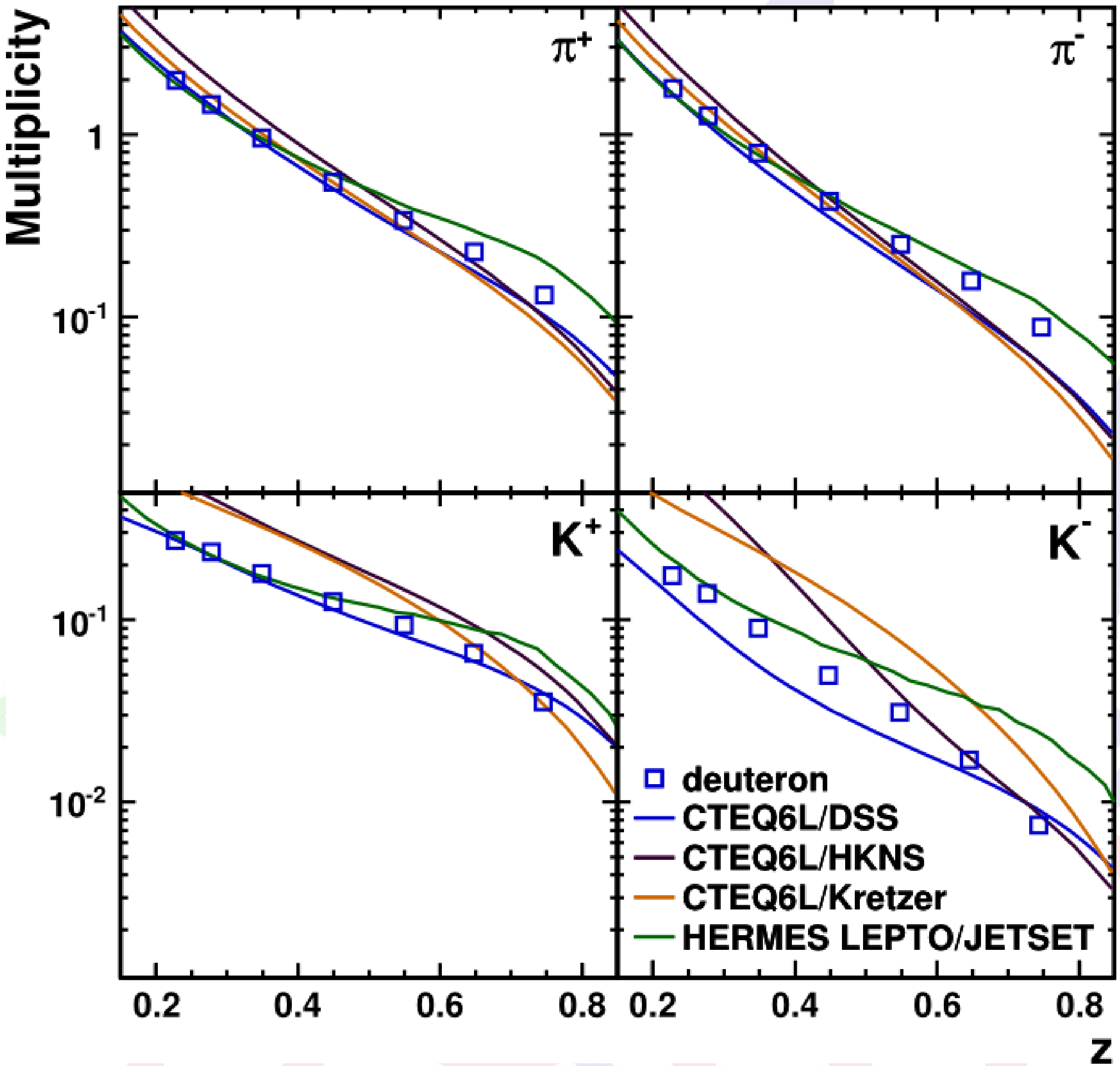
Proton target

NLO calculations(DSS+)

- **Much better agreement for both π^+ and π^-.**

- **Workshop on fragmentation functions, Bloomington, 2013**

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



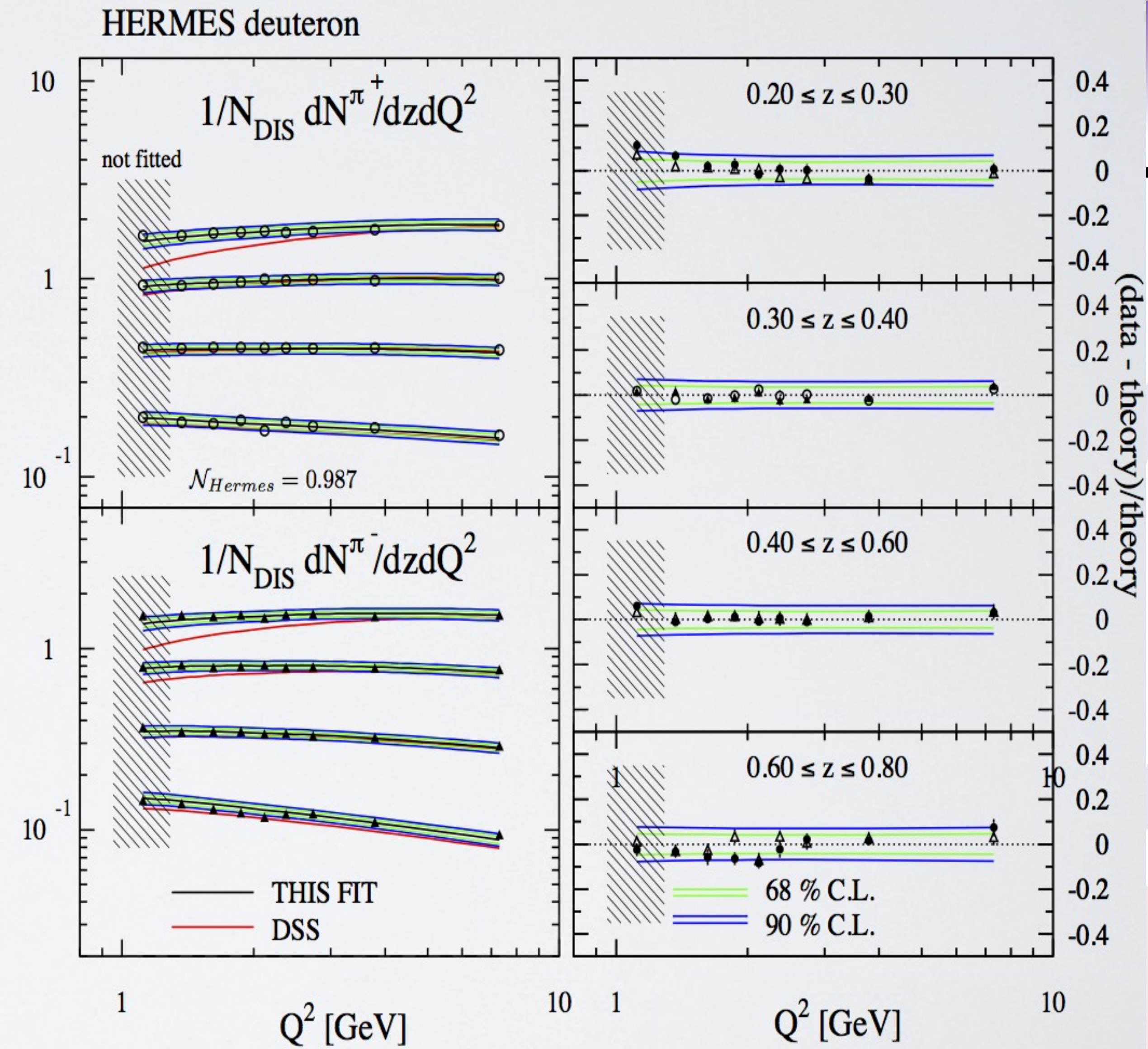
Deuteron target

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.**

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



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DIS event yields

Experimental observable

SIDIS hadron yields

Beyond the collinear approach

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

DIS event yields

Flavor-dependent Gaussian ansatz

$$f_q\left(x_B, Q^2, k_\perp^2\right) = f_q\left(x_B, Q^2\right) \frac{1}{\pi < k_{\perp,q}^2 >} e^{-k_\perp^2 / < k_{\perp,q}^2 >}$$

$$D_q^h\left(z, Q^2, p_\perp^2\right) = D_q^h\left(z, Q^2\right) \frac{1}{\pi < p_{\perp,q\to h}^2 >} e^{-p_\perp^2 / < p_{\perp,q\to h}^2 >}$$

$$< P_{h\perp,q}^2 > = < p_{\perp,q\to h}^2 > + z^2 < k_{\perp,q}^2 >$$

A. Signori, A. Bacchetta, M. Radici and G. Schnell(JHEP, 2013)

Flavor-dependent Gaussian ansatz

$$f_q(x_B, Q^2, k_\perp^2) = f_q(x_B, Q^2) \frac{1}{\pi \langle k_{\perp,q}^2 \rangle} e^{-k_\perp^2/\langle k_{\perp,q}^2 \rangle}$$

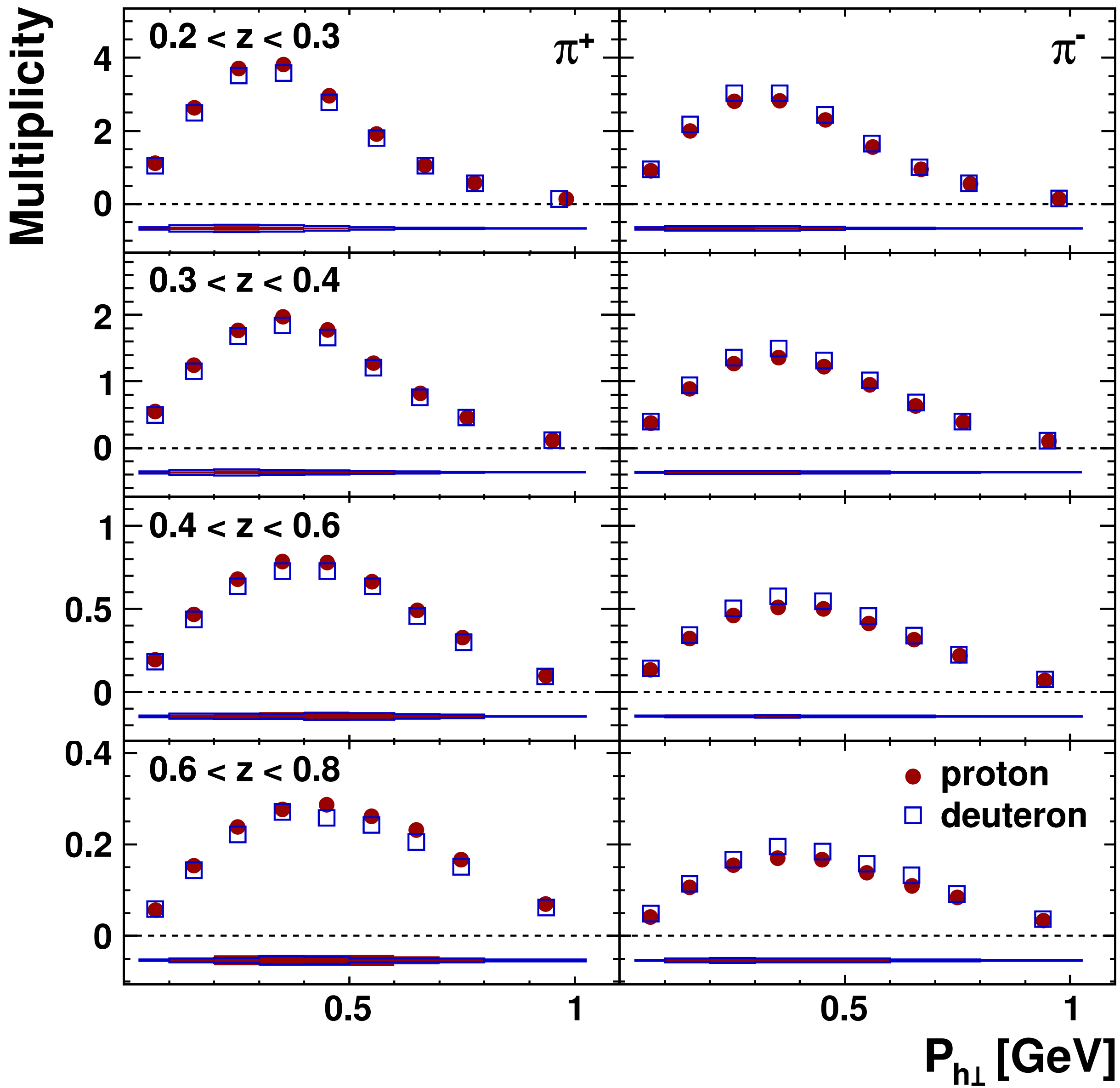
PDF

$$\int f_q(x_B, Q^2, k_\perp^2) d^2 k_\perp$$

$$\int D_q^h(z, Q^2, p_\perp^2) d^2 p_\perp$$

$$D_q^h(z, Q^2, p_\perp^2) = D_q^h(z, Q^2) \frac{1}{\pi \langle p_{\perp,q\to h}^2 \rangle} e^{-p_\perp^2/\langle p_{\perp,q\to h}^2 \rangle}$$

FF

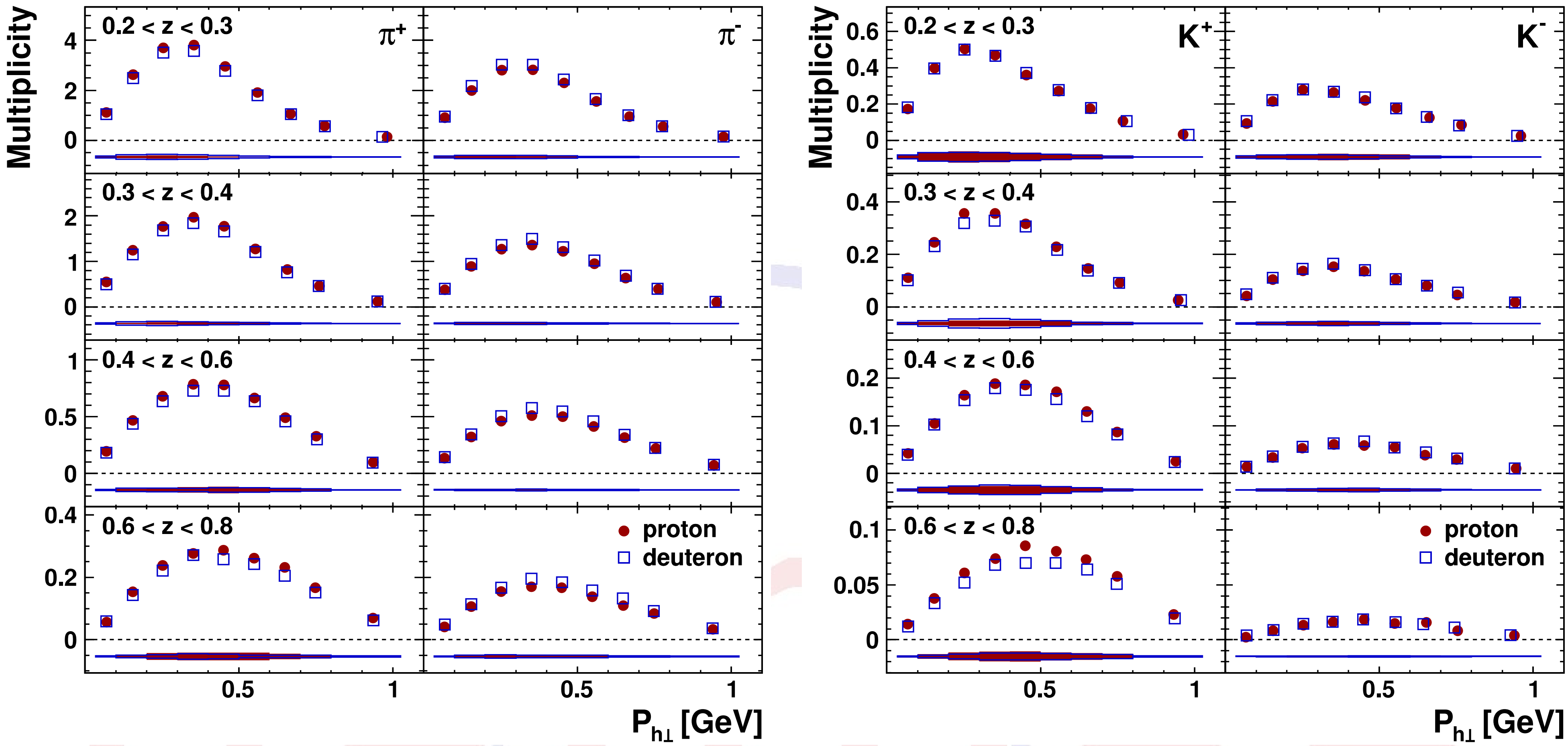


$M^h(x_B, Q^2, z, P_{h\perp})$

Arises from combined effect : initial transverse motion of the struck quark and the transverse momentum component generated by the fragmentation process :

$$\vec{P}_{h\perp} = z\,\vec{k}_\perp + \vec{p}_\perp - O\left(\frac{k_\perp^2}{Q^2}\right)$$

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



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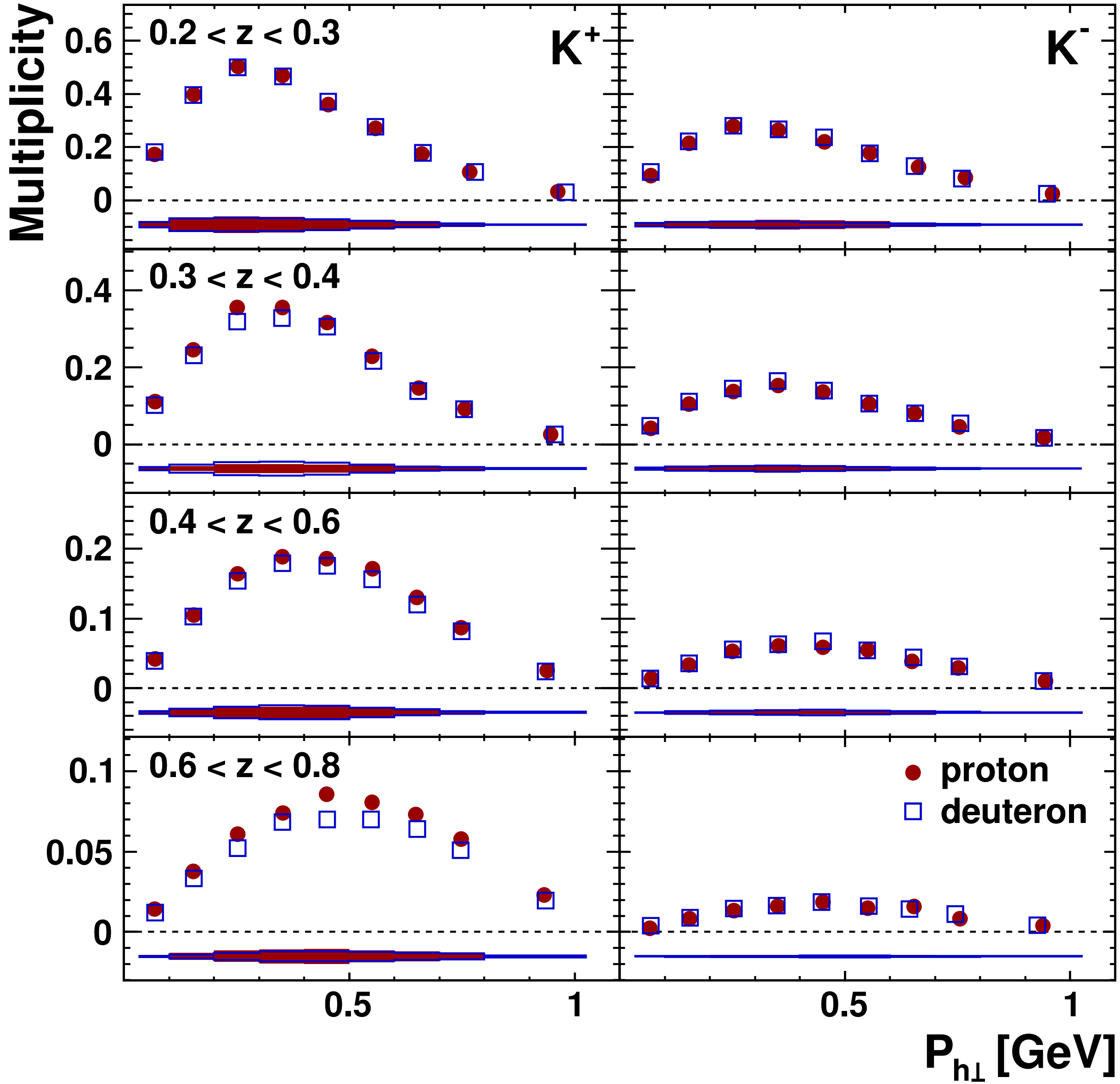
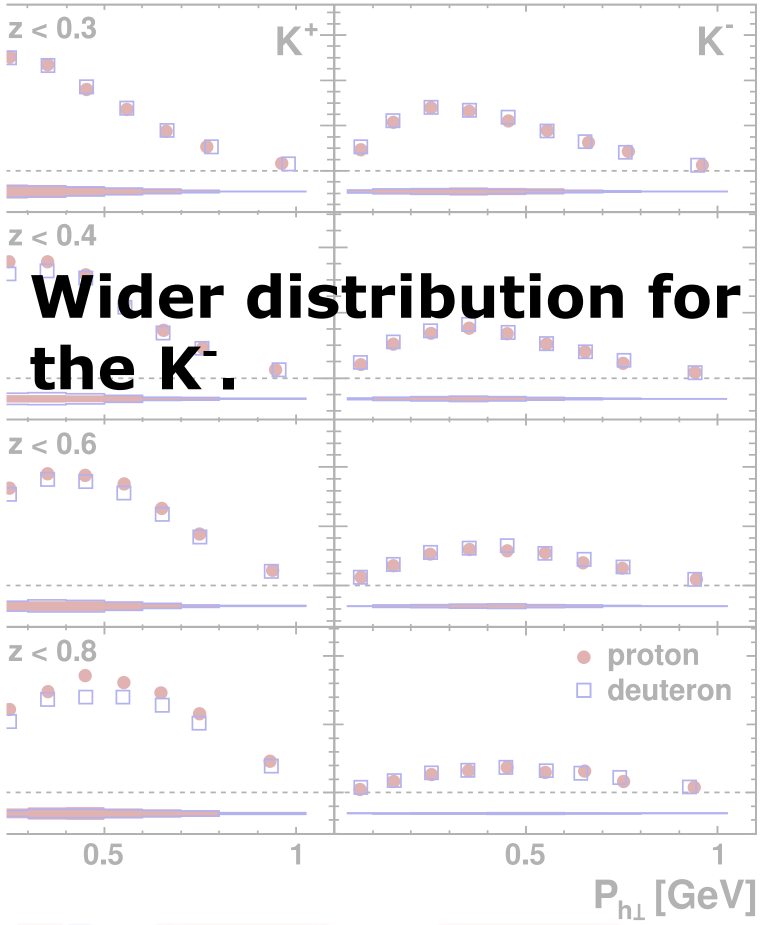
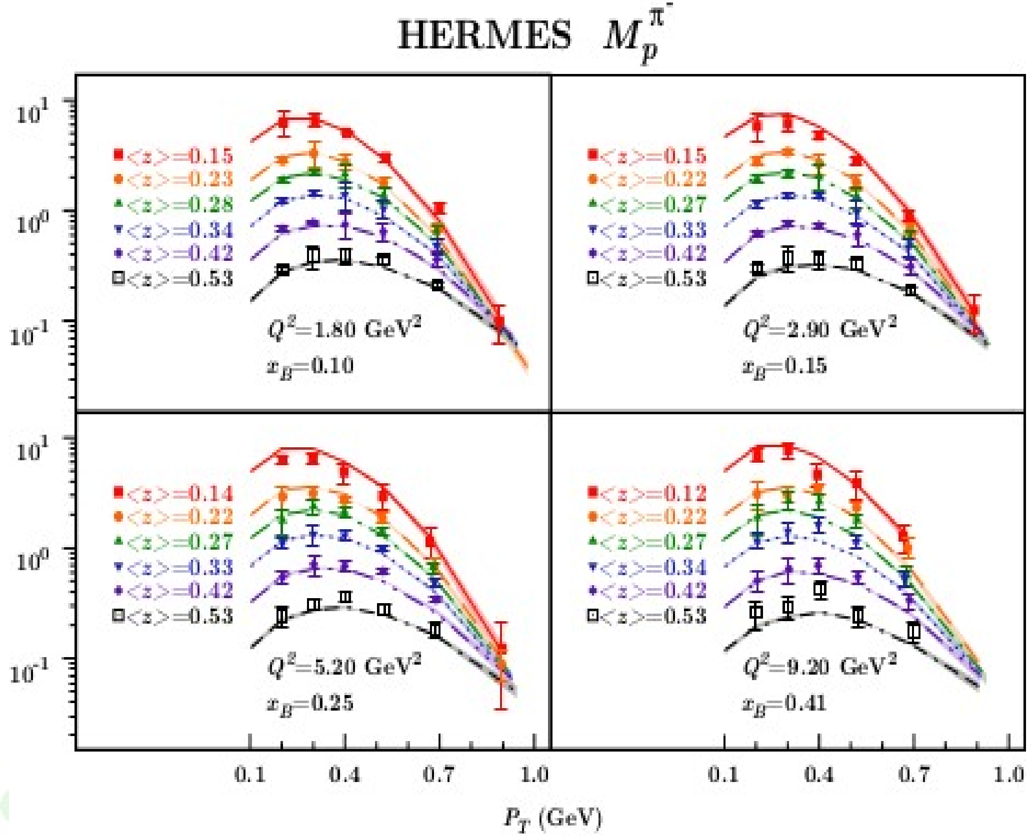
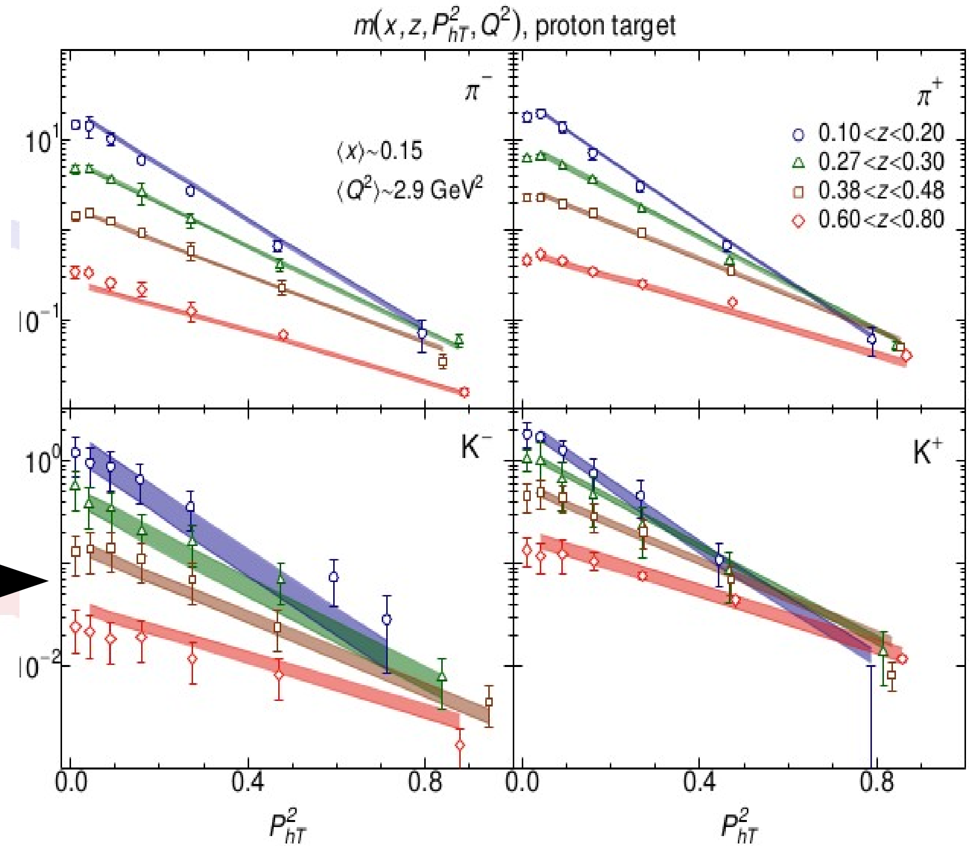




Wider distribution for the K-.



M. Anselmino, M. Boglione, J.O. Gonzalez H., S. Melis, A. Prokudin JHEP (2014)



A. Signori, A. Bacchetta, M. Radici and G. Schnell JHEP (2013)

(**hadron multiplicities**)

A. Airapetian et. al, Phys. Rev. D87 (2013) 074029
http://www-hermes.desy.de/multiplicities

Extract strange quark distribution

$S(x,Q^2) \int D_S^K(z,Q^2)dz \approx$

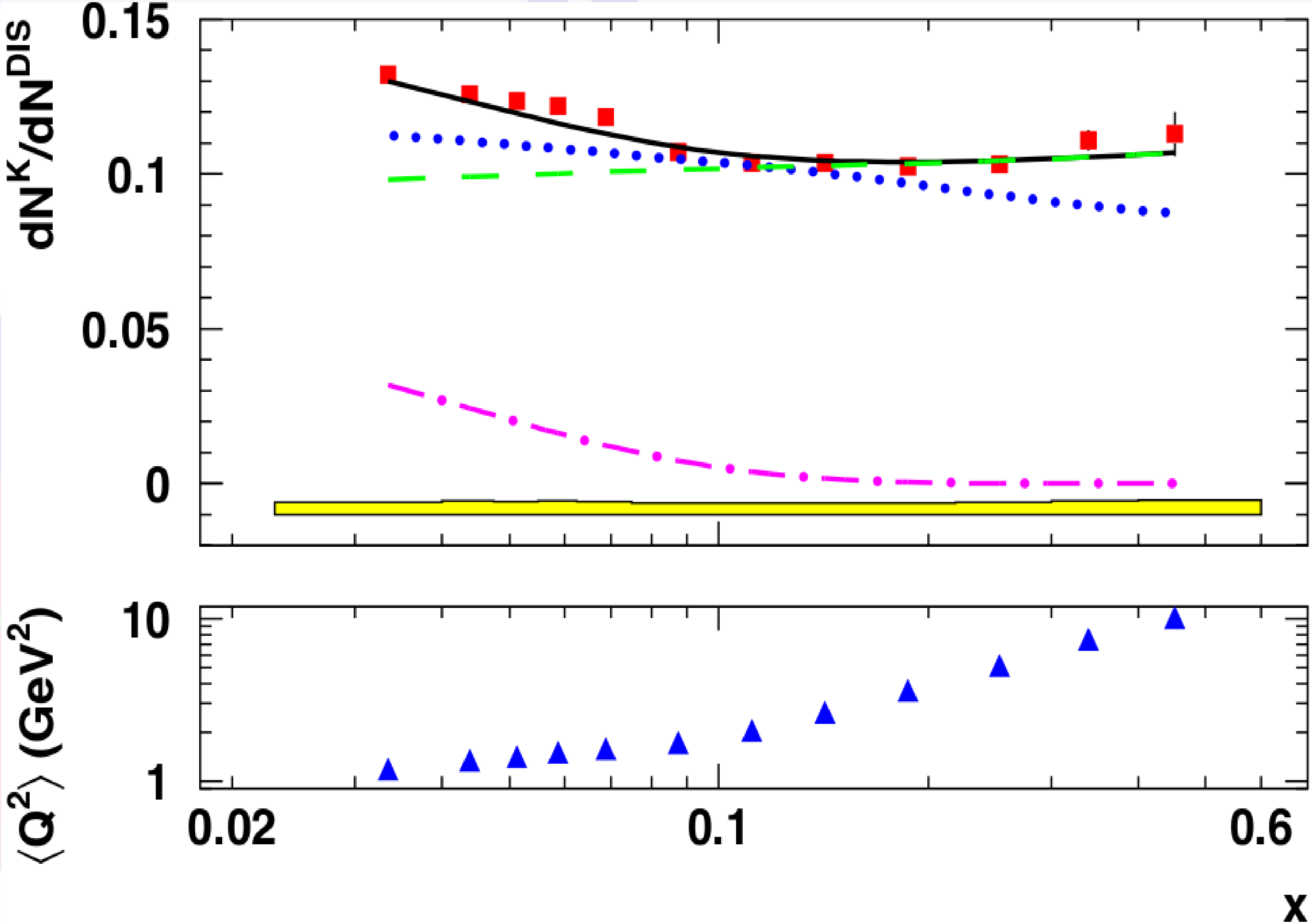
$\mathcal{Q}(x,Q^2)$ [$5\, dN^K(x,Q^2)/dN^{DIS}(x,Q^2)$-

$- \int D_Q^K(z,Q^2)dz$]

$K = K^+ + K^-$, $S(x,Q^2) = s(x,Q^2) + \bar{s}(x,Q^2)$,

$\mathcal{Q}(x,Q^2) = u(x,Q^2) + \bar{u}(x,Q^2) + d(x,Q^2) + \bar{d}(x,Q^2)$

Kaon multiplicity sum



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$$Q(x,Q^2)\,[\,5\,dN^K(x,Q^2)/dN^{DIS}(x,Q^2) -$$

$$-\int D_Q^K(z,Q^2)dz\,]$$

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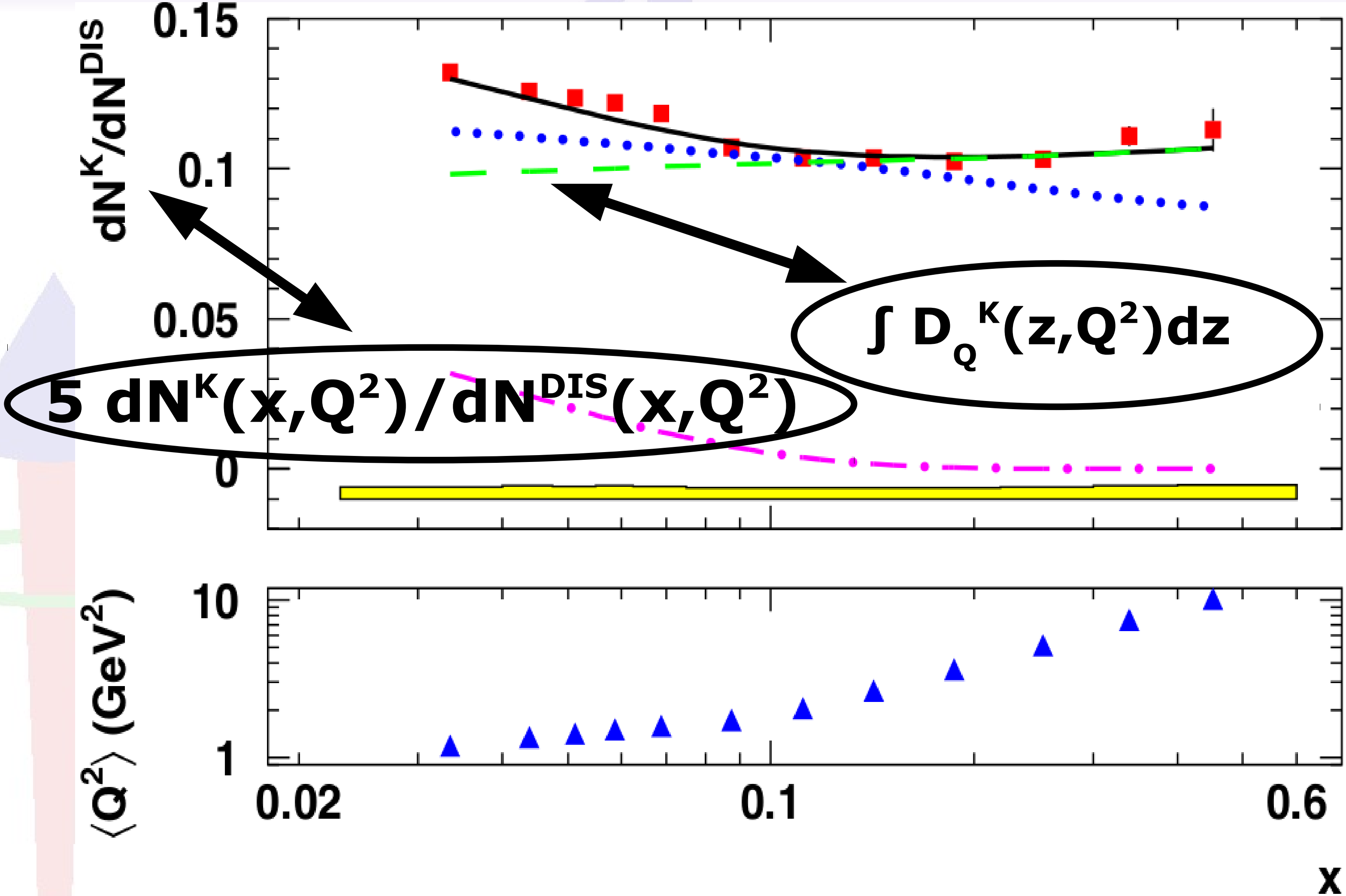

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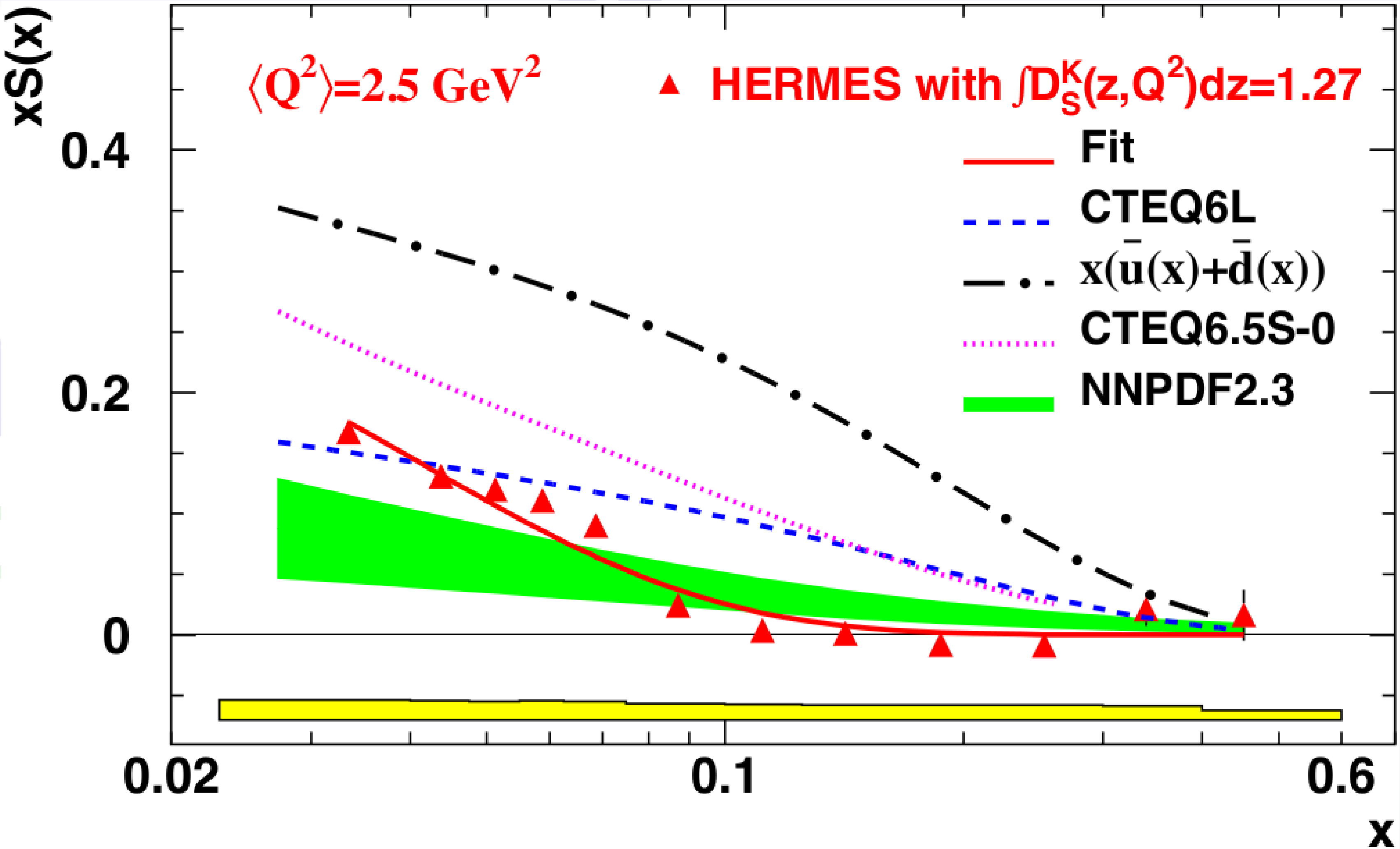
Strange quark distribution



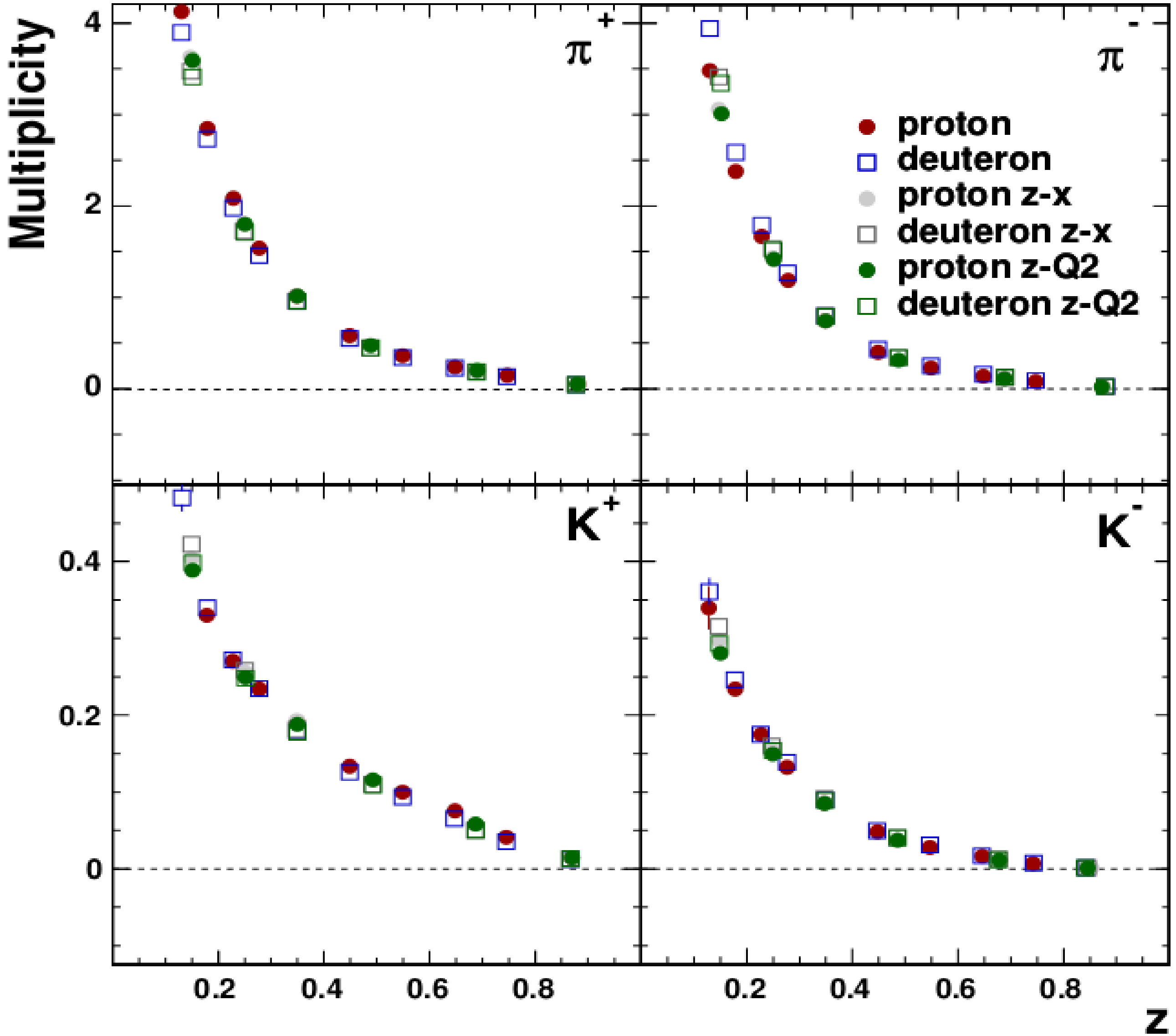
(strange quark distribution)

A. Airapetian et. al, Phys. Rev. D89 (2014) 097101

Summary

- High statistical data set for positively/negatively charged pion and kaon multiplicities on proton and deuteron.
- The extracted multiplicities integrated over hadron transverse momentum give an access to collinear fragmentation functions.
- Dependence of multiplicities on hadron transverse momentum provides constraints on transverse momentum dependent distribution and fragmentation functions.
- Strange quark distribution is extracted from kaon multiplicity sum using data from deuteron target.

Backup



Multiplicity
π+
π-
K+
K-
proton
deuteron
proton z-x
deuteron z-x
proton z-Q2
deuteron z-Q2
z