HERMES measurements of charge separated multiplicities for $\pi^{\pm}$ and $K^{\pm}$ production in semi-inclusive DIS

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SIDIS Multiplicities

Definition

$$\frac{d^2\mathcal{M}_t^h(Q^2,x,z,p_T)}{dzdp_T} \equiv \frac{dxdQ^2}{d^2N_t^{\mathrm{DIS}}(Q^2,x)} \frac{d^4N_t^h(Q^2,x,z,p_T)}{dxdQ^2dzdp_T}$$

- DIS yield $N_t^{\mathrm{DIS}}(Q^2,x)$
- SIDIS yield $N_t^h(Q^2,x,z,p_T)$

SIDIS Multiplicities

Example: LO Framework

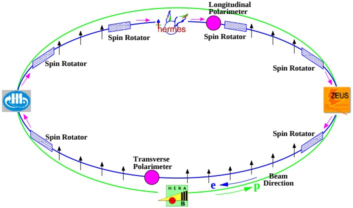
$$\frac{d\mathcal{M}_n^h(Q^2,x,z)}{dz} \approx \frac{\sum_q e_q^2 f_1^q(Q^2,x)\mathcal{D}_q^h(Q^2,z)}{\sum_q e_q^2 f_1^q(Q^2,x)}$$

$$\frac{\text{SIDIS}}{\text{DIS}}$$

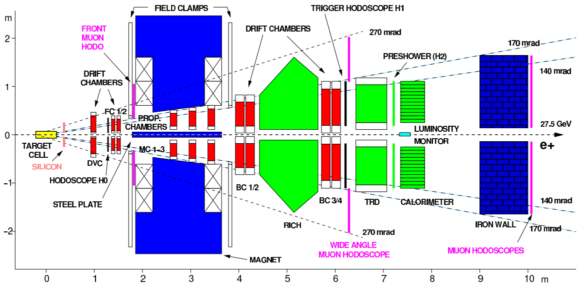
Assumptions: QPM, LO, leading twist factorized colinear QCD

- Opens access to
  - Fragmentation functions $\mathcal{D}_q^h(Q^2,z)$,
    - ⋆ Disentangle q and $\bar{q}$ contributions
  - Parton distribution functions $f_1^q(Q^2,x)$
- Additionally, through the p_T dependence
  - Fragmentation k_T
  - Intrinsic quark p_T

The HERMES Experiment



- 27.6 GeV HERA electron/positron beam
- Pure H and D gas target
- Forward spectrometer
- Very clean lepton-hadron separation
- RICH detector enables very good pion-kaon separation



- $W^2 > 10\text{GeV}^2$
- $0.1 < y < 0.85$
- $Q^2 > 1\text{GeV}^2$
- $0.023 < x < 0.6$

SIDIS Multiplicities: New HERMES Results

- High statistics
- 3D analysis (in x, z, p_T and Q^2, z, p_T)
- For identified and charge-separated $\pi^{\pm}$ and $K^{\pm}$
- High precision data require sophisticated analysis:

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  - Corrections for detector efficiencies
  - 3D unfolding for smearing and acceptance effects
  - In-depth systematics analysis
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- High precision 3D data pushes the envelope, enabling:
  - Evaluation of the quality of PDF and FF parametrizations
  - Improvements on the current parametrizations
  - Access to the transverse fragmentation function
  - Tests of the applicability of the usual colinear LO, leading-twist model assumptions in the HERMES kinematic regime

Unfolding the SIDIS Multiplicities

Relation between true and measured quantities

$$\nu_i = \mu_{\mathrm{tot}} \sum_{j=1}^{M} \frac{\int_{\mathrm{bin}\,i} \mathrm{d}X \int_{\mathrm{bin}\,j} \mathrm{d}Y s(X|Y)\epsilon(Y) f(Y)}{\int_{\mathrm{bin}\,j} \mathrm{d}Y f(Y)} \mu_j + \beta_i$$

- Measured quantity ν_i in bin i (eg. differential cross section)
- True quantity μ_j in bin j following the true distribution $f(Y)$
- Properties of the experiment:
  - Resolution function $s(X|Y)$
    - Experimental resolution
    - Radiative effects
  - Acceptance function $\epsilon(Y)$
- Background contributions β_i in bin i

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- Has the shape of a matrix equation

$$\nu_i = \sum_{j=1}^{M} S_{ij} \mu_j + \beta_i$$

- Smearing matrix S independent of underlying physics f if bins small enough
- Extracted from MC simulation

Unfolding the SIDIS Multiplicities

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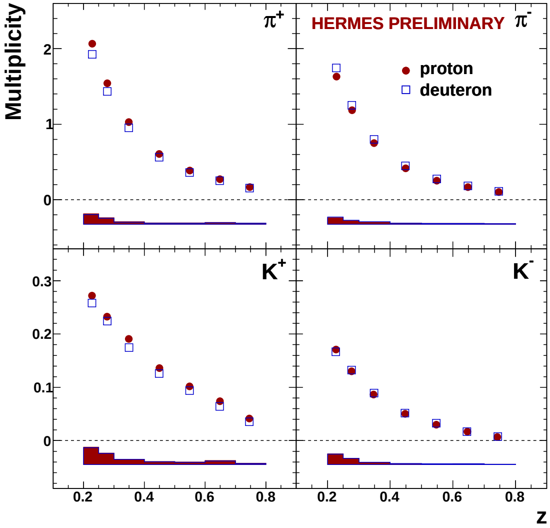
- Solve for true data by simple matrix inversion

$$\mu_j = \sum_{i=1}^{M} S_{ji}^{-1}(\nu_i - \beta_i)$$

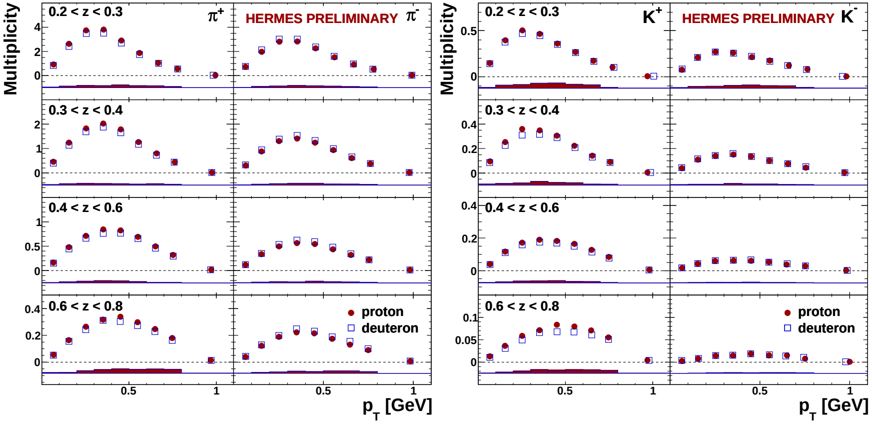
- Resulting multiplicity corrected for
  - Limited acceptance
  - Finite detector resolution
  - Radiative smearing

Results: Projections vs z



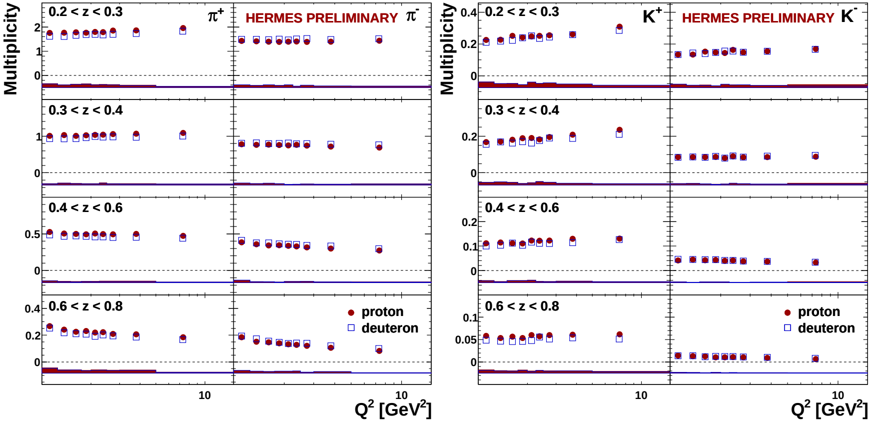
Results: Projections vs zp_T

- Disentanglement of z and p_T
- Access to the transverse intrinsic quark p_T and fragmentation k_T.

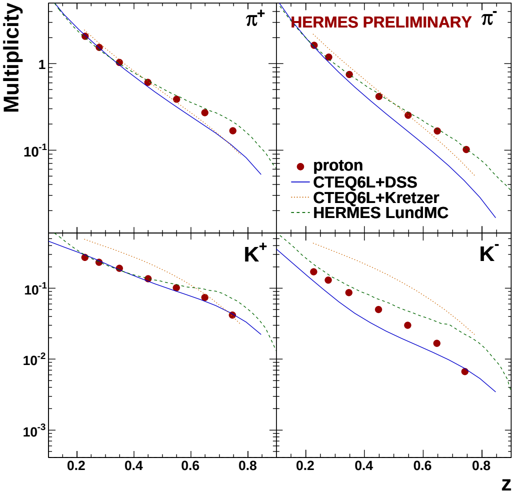


Results: Projections vs zQ^2

- Disentanglement of z and Q^2



Comparison with Predictions: Projections vs z

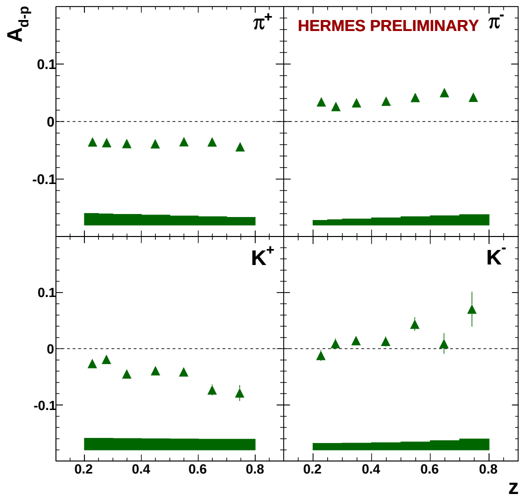


LO Interpretation

- Good agreement with CTEQ6+DSS for π^+ and K^+
- CTEQ6+Kretzer performs well for pions
- Larger deviations for π^-
- Agreement with K^- rather poor

- **Model uncertainty?**

Proton-deuteron multiplicity asymmetry



definition:

$$A^h_{d-p} \equiv \frac{\mathcal{M}^h_d - \mathcal{M}^h_p}{\mathcal{M}^h_d + \mathcal{M}^h_p}$$

- Reflects different valence quark content
- Improved precision by cancellations in the systematic uncertainty

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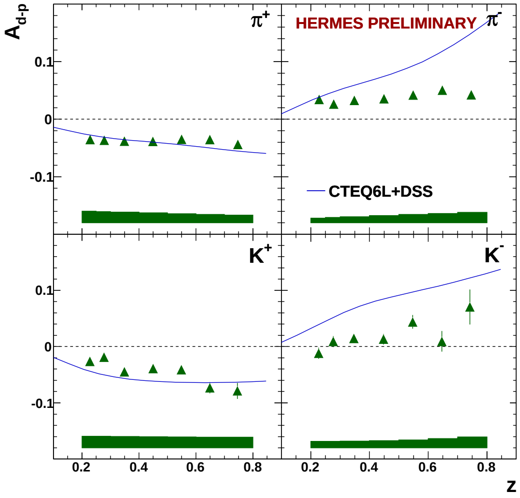

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$$A^h_{d-p} \equiv \frac{\mathcal{M}^h_d - \mathcal{M}^h_p}{\mathcal{M}^h_d + \mathcal{M}^h_p}$$

LO Interpretation:

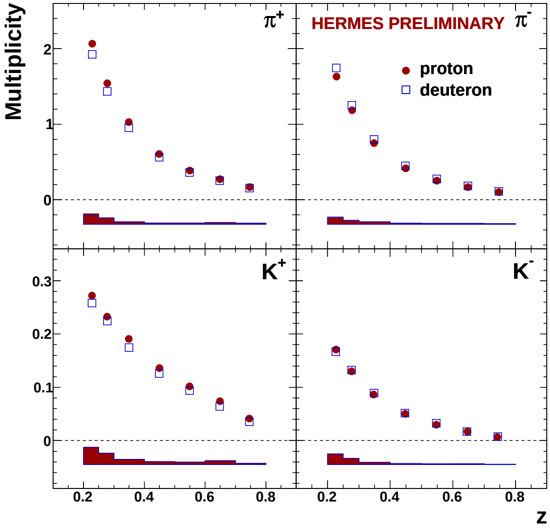
- Good agreement with LO model calculations for positive hadrons
- Bigger discrepancy for negative hadrons
- **Model uncertainty?**

Conclusions

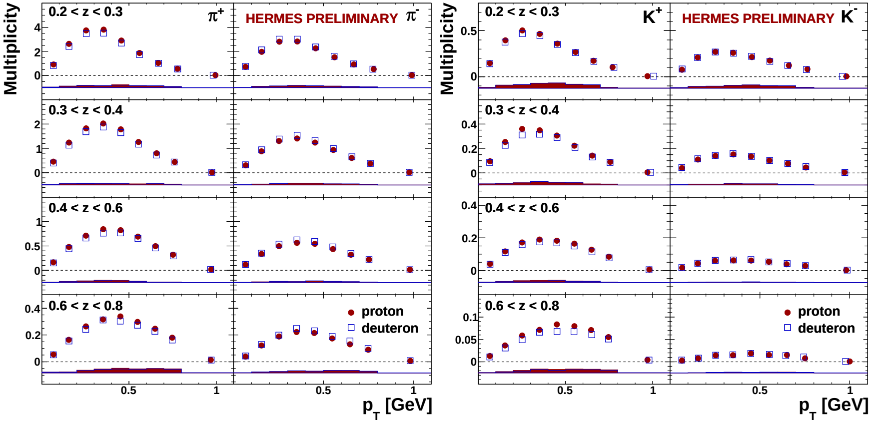
- Unique set of 3D high-precision SIDIS multiplicities for $\pi^{\pm}$ and $K^{\pm}$ on p and d are presented
- By using asymmetries and difference ratios, the precision can be improved even further due to cancellations in the systematic uncertainties
- High value for NLO fits
- Data can significantly contribute to knowledge of the quark fragmentation process

BACK-UP SLIDES

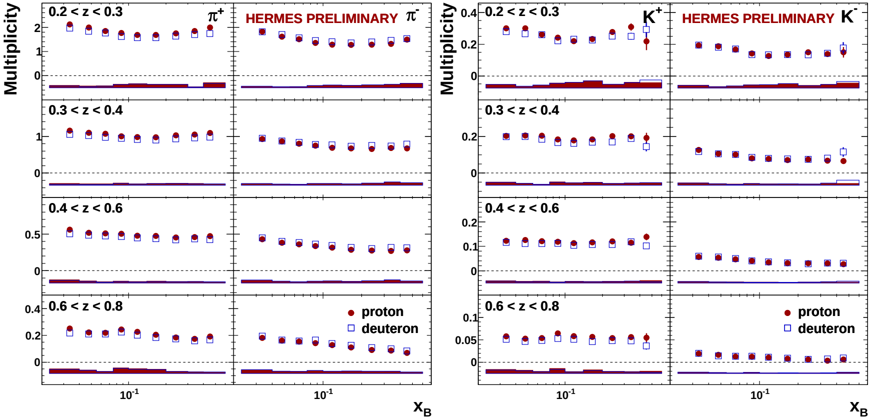
Full Results: Projections vs z



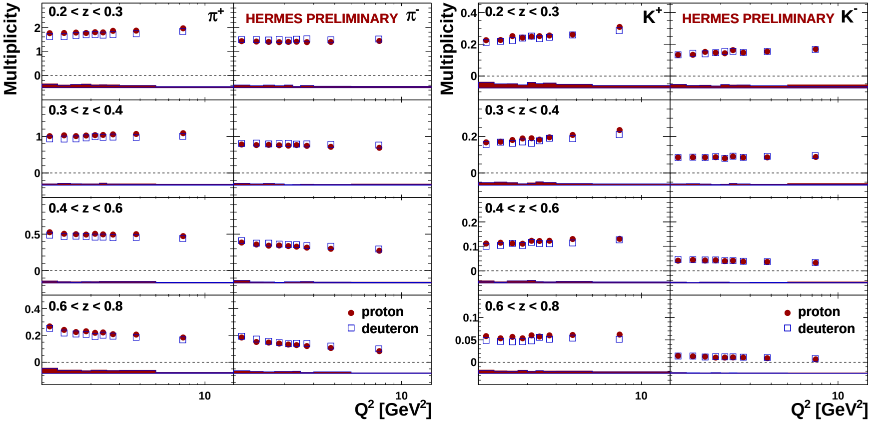
Full Results: Projections vs zp_T



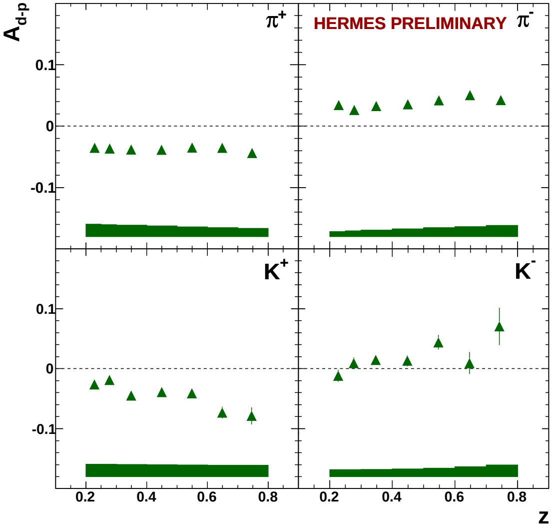
Full Results: Projections vs zx



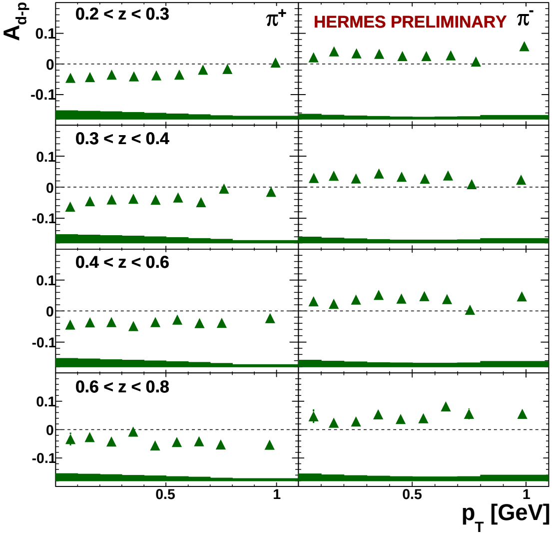
Full Results: Projections vs zQ^2



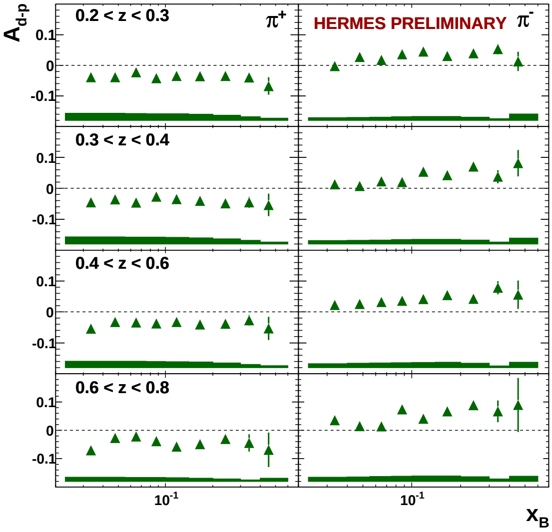
Full Results: Asymmetries vs z



Full Results: Asymmetries vs zp_T



Full Results: Asymmetries vs zx



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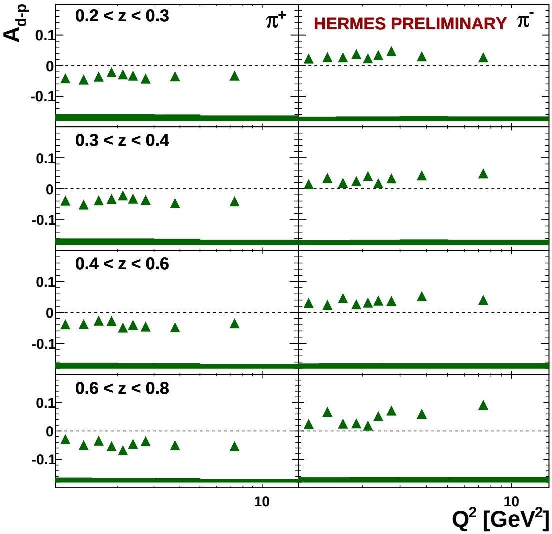
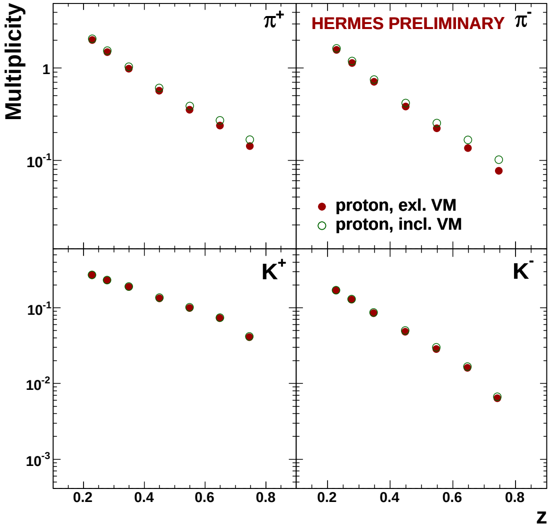
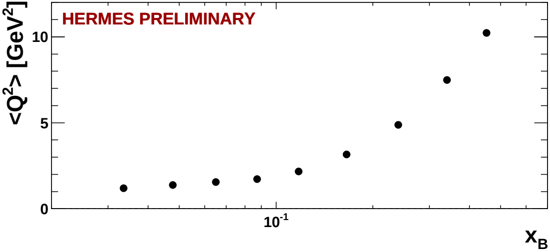


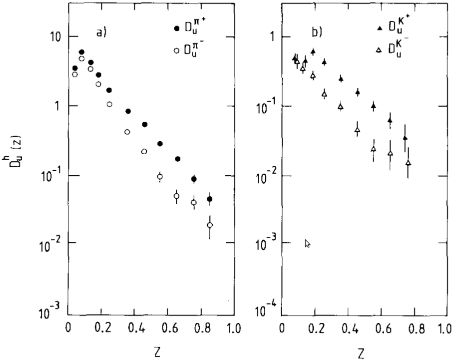
Impact of exclusive VM fractions



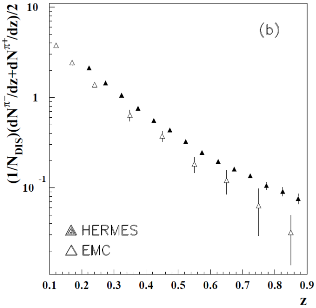
Average Q^2 as a function of x



SIDIS Multiplicities: Historical



EMC FFs
Nucl.Phys. B321 (1989) 541



HERMES multiplicities
1996-97 data
Eur.Phys.J. C21 (2001) 599-606