Multiplicities of $\pi^{\pm}$ and $K^{\pm}$ Production in Semi-inclusive DIS on a Proton and Deuteron Target

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Goals

- Provide the most precise multi-dimensional dataset from semi-inclusive DIS (SIDIS) to date
- Evaluation of the quality of modern parametrizations for fragmentation functions (FFs) and parton distribution functions (PDFs)
- Input for the next generation of parametrizations
- Multidimensional access to transverse momentum distributions
- Invaluable information for future experiments
  - Test the applicability of a LO, leading twist approach at intermediate energies
  - Investigate the limits of the analysis techniques

Extracting SIDIS Multiplicities at HERMES

- Hydrogen and deuterium atomic gas target
  - No dilution due to nuclear effects
  - Effectively pure proton and deuteron targets
- Correction for trigger inefficiencies
  - Based on momentum and event topology
- Lepton-hadron separation
  - Uses the combined response of a TRD, a RICH, a preshower detector and a lead-glass calorimeter
  - Lepton-hadron separation > 98% with <1% contamination
- Charge-symmetric background correction
- Pion-kaon separation
  - RICH detector
  - Event-level direct ray tracing (EVT) algorithm yields hadron type
  - Construct probability $P_{h1,h2}$ that $h1$ is misidentified as $h2$
  - Use the inverse of the P-matrix to unfold to the true particle types
  - π, K and p are considered during RICH unfolding
- Smearing-unfolding to correct for radiative effects, limited acceptance and detector smearing
  - Effects lead to bin-to-bin migration and a detection efficiency < 100%
  - Evaluated using 2 Monte Carlo simulations
  - Probabilistic information summarized in the smearing matrix S
  - Solve matrix equation to obtain Born level multiplicities
  - Resulting covariance matrix not diagonal!

Selection of a Clean SIDIS Sample

- DIS regime: $Q^2 > 1\,\text{GeV}^2$
- Avoid resonance region: $W^2 > 10\,\text{GeV}^2$
- Optimal resolution and trigger efficiency: $y > 0.1$
- Avoid large radiative corrections: $y < 0.85$
- Supress target fragmetation: $z > 0.2$
- Exclude exclusive region: $z < 0.8$

Systematic Uncertainties

- Time dependence to account for detector fluctuations between 2000–2005
- MC model dependence of the smearing-unfolding
- Azimuthal modulations of the SIDIS cross section neglected during acceptance correction
- EVT algorithm sensitive to PMT background hit assumption.

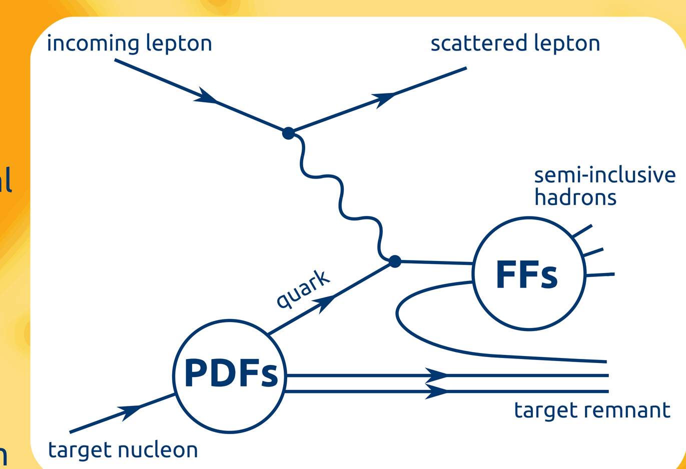
Multi-dimensional Multiplicities

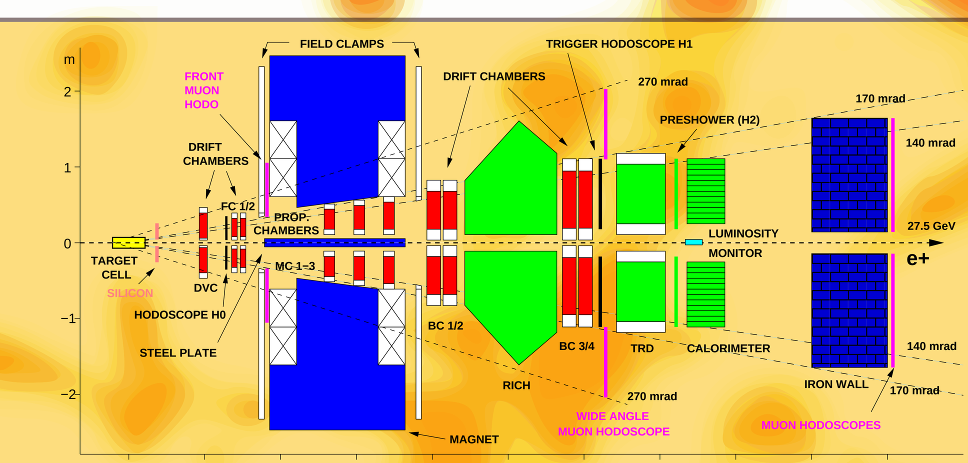
- 3D analysis (in x, z, p_T and Q^2, z, p_T)

$$M_t^h(Q^2, x, z, p_T) = \frac{dxdQ^2}{d^2N_t^{DIS}(Q^2, x)}\,\frac{d^4N_t^h(Q^2, x, z, p_T)}{dxdQ^2dzdp_T}$$

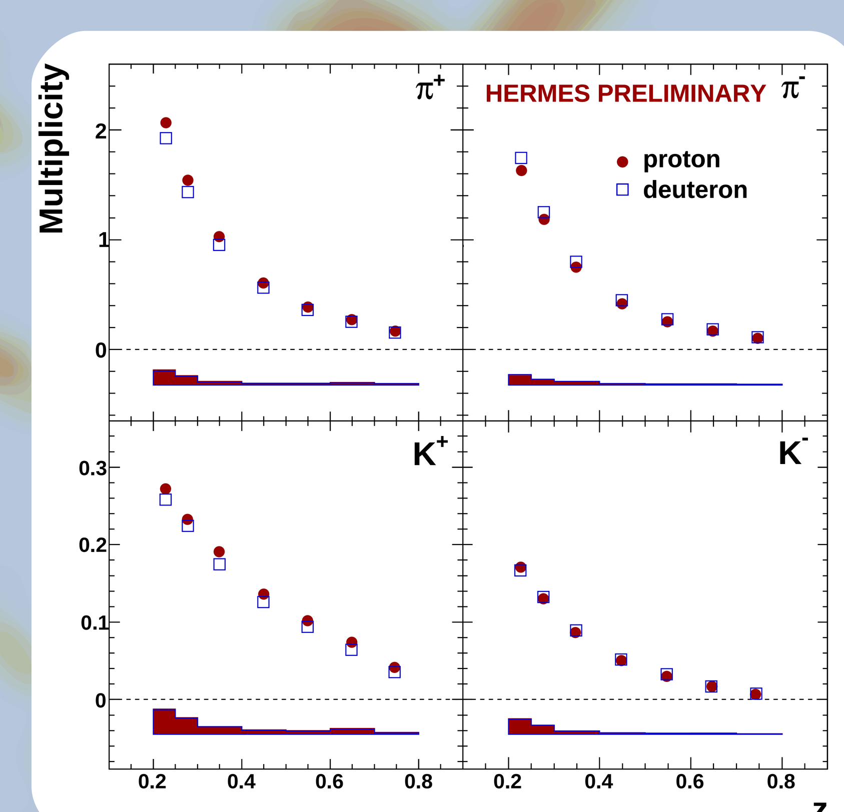
Definitions and LO SIDIS Diagram

- Q^2 - photon virtuality
- W^2 - invariant mass squared of the photon-nucleon system
- y - fractional energy of the virtual photon
- x - fractional momentum of the struck quark
- z - fractional energy of the produced hadron
- p_T - transverse hadron momentum





Results: Projection vs z



- π^+ multiplicities are higher than π^- multiplicities due to u-quark dominance
- K^- cannot be produced by favored fragmentation from valence quarks
- Lower fraction of u-quarks in deuteron, and higher fraction of d-quarks
- Systematic uncertainties between different particles and targets are partially correlated
- Evaluating asymmetries and difference ratios increases the precision even further

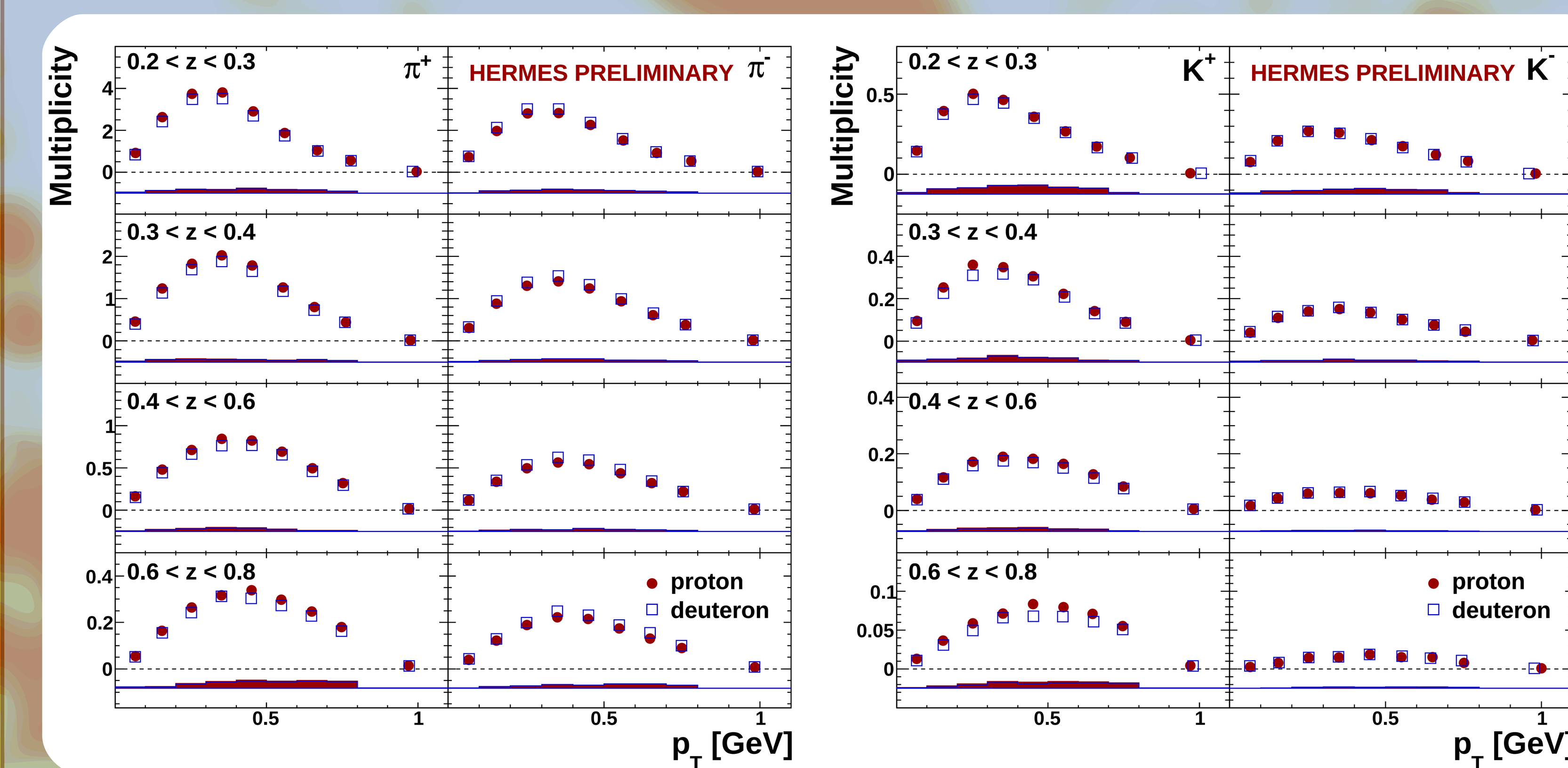
Target Comparison

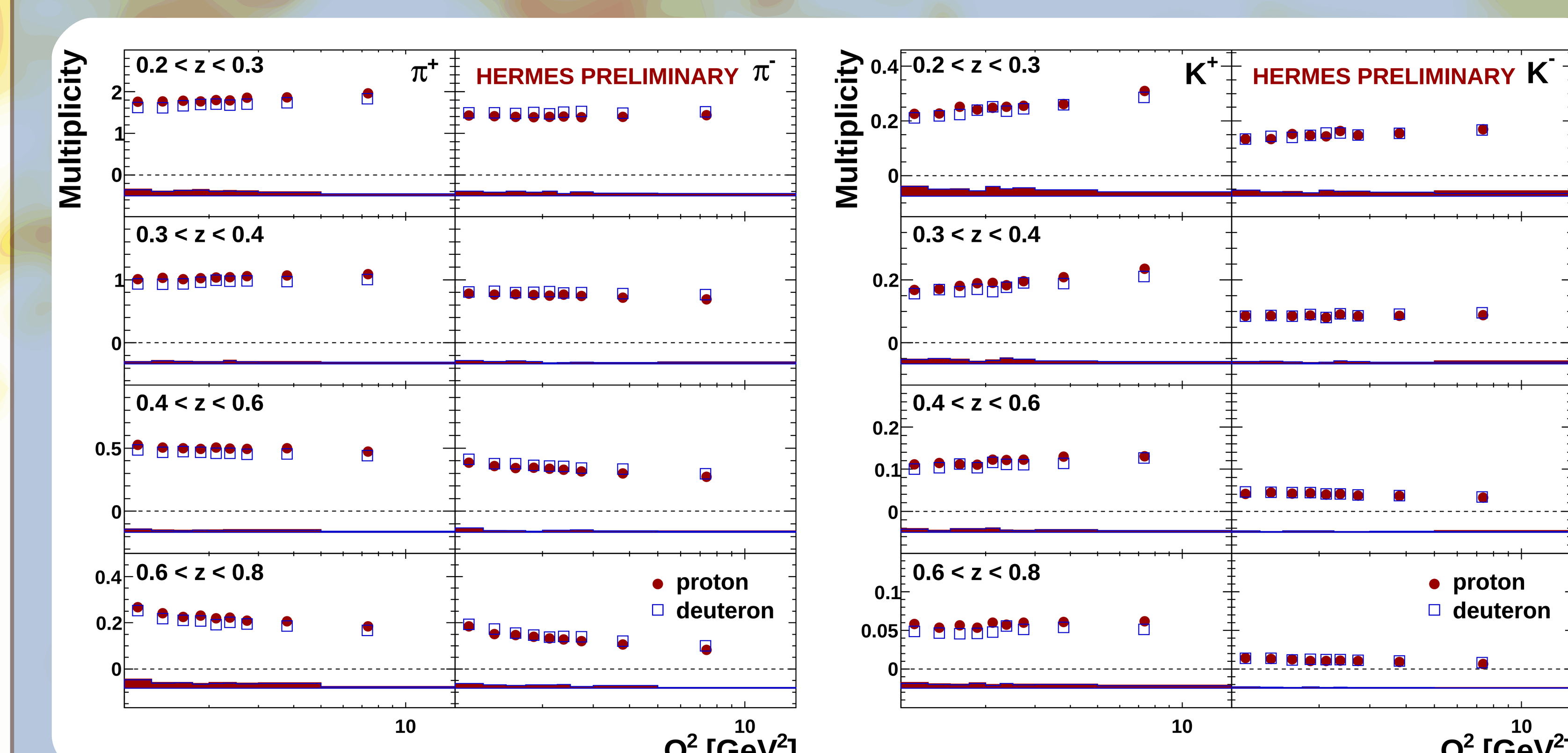
- Reflects the different valence quark content of proton and deuteron
- Improved precision due to cancellations in the systematic uncertainties

$$A^h_{d\text{-}p} = \frac{M^h_d - M^h_p}{M^h_d + M^h_p}$$

Results: Projection vs p_T and Q^2 in z slices

- Disentanglement of (z, p_T) and (z, Q^2), third dimension is projected out





Comparison with LO Predictions

- DSS FFs perform very well for positive hadrons
- Poor agreement for negative hadrons: room for improvement in the disfavored sector