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 (SIDS) 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 target
- 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 0.3% contamination
- Charge-symmetric background correction
- Pion-kaon separation
  - RICH detector
  - Event level: direct tagging (VFF) algorithm yields hadron type
  - Construct probability $P_{\pi K}$ that it is misidentified as $K^\pm$
  - Use the inverse of the $P_{\pi K}$ matrix to unfold to the true particle types
  - $\pi$, $K$ and $p$ considered during RICH unfolding
- Smearing-unfolding to correct for radiative effects, limited acceptance and detector smearing
  - Effects lead to bin-to-bin migrations and a detection efficiency < 100%
  - Evaluated using 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: $Q^2 > 1$ GeV\(^2\)
- Avoid resonance region: $MP > 10$ GeV\(^2\)
- Optimal resolution and trigger efficiency $x > 0.1$
- Avoid large radiative corrections, $y > 0.1$
- Suppress target fragmentation: $z > 0.2$
- 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
- Adjoint modulations of the DIS cross section neglected during acceptance correction
- BVT algorithm sensitive to PMT background hit assumption

Definitions and LO SIDIS Diagram
- $Q^2$ - photon virtuality
- $x$ - fractional energy of the virtual photon
- $y$ - fractional energy of the produced hadron
- $p_T$ - transverse hadron momentum

Multi-dimensional Multiplicities
- 3D analysis ($x$, $z$, $p_T$, and $Q^2$, $z$, $p_T$)

$$ M_0(Q^2, x, z, p_T) = \frac{dx^2}{d^2N_0(Q^2, x)} d^2Q^2 dx dp_T, $$

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

Results: Projection vs $z$
- $\pi^\pm$ multiplicities are higher than $K^\pm$ multiplicities due to quark dominance
- $K$ cannot be produced by favored fragmentation from valence quark
- Lower fraction of squarks in deuterium, and higher fraction of squarks
- Systematic uncertainties between different particles and targets are partially correlated
- Evaluating asymmetries and difference ratios increases the precision even further

Comparison with LO Predictions
- DIS FFs perform very well for positive hadrons
- Poor agreement for negative hadrons, room for improvement in the disfavored sector

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

$$ A_T^\pm = \frac{M_0^\pm - M_0^-}{M_0^+ + M_0^-} $$