KAON MULTIPlicITIES IN SIDIS
FROM COMPASS

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on behalf of the COMPASS collaboration
DIS 2019 - XXVII International Workshop on Deep Inelastic scattering and related subjects
**MOTIVATION : STRANGE QUARK SEA POLARIZATION FROM SIDIS**

- $\Delta S$ form Semi-Inclusive Asymmetries strongly linked to quark fragmentation, especially the strange one, poorly known:

$$2 \Delta S = f(R_{SF}), \quad R_{SF} = \frac{\int D_{S}^{K^{+}}(z)dz}{\int D_{u}^{K^{+}}(z)dz}$$

Discrepancy on $\Delta S$ between inclusive and semi-inclusive.

Goal is to extract better kaon fragmentation function from COMPASS data and determine $R_{SF}$.

**COMPASS PLB 680 (2009) 217**


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April 9, 2019
What is a SIDIS hadron multiplicity measurement?

One can express the differential cross section for hadron production normalized to the differential inclusive DIS cross section by:

$$
\frac{dM^h(x, Q^2, z)}{dz} = \frac{d^3\sigma^h(x, Q^2, z)/dx dQ^2 dz}{d^2\sigma(x, Q^2)/dx dQ^2}
$$

This can also be expressed, in LO pQCD, as a function of Parton Distribution Functions (PDFs) and Fragmentation Functions (FFs):

$$
\frac{dM^h(x, Q^2, z)}{dz} = \frac{\sum_q e_q^2 q(x, Q^2) D_q^h(z, Q^2)}{\sum_q e_q^2 q(x, Q^2)}
$$
Fixed target experiment at CERN SPS
Operates with muon or hadron beams
This analysis: 160 GeV $\mu^+/\mu^-$ beam (2016)

- RICH: excellent charged $\pi$, K, p discrimination
- This analysis: 2 m long, IH$_2$ pure proton target (2016)
**COMPASS KINEMATICS**

**PRELIMINARY**

- \( E_\mu = 160 \text{ GeV} \)
- \( Q^2 > 1 \text{ (GeV/c)^2} \)
- \( W > 5 \text{ GeV/c}^2 \)
- \( 0.004 < x < 0.4 \)
- \( 0.1 < y < 0.7 \)
- \( 0.2 < z < 0.85 \)
**MULTIPICLITY ANALYSIS**

**COMPASS Raw Data**

- Event and particle reconstruction
- Event and particle selection
- RICH PID
- RICH unfolding
- Detector acceptance
- Kinematic bin smearing
- Electron contamination *
- Diffractive vector meson correction
- Radiative correction

**Corrections**

(* Because RICH discrimination btw e⁻/π only works at low momenta (<8 GeV), necessary for pion/unidentified hadron multiplicities)

**Final Multiplicities**

\[
\frac{dM_h(x, y, z)}{dz} = \frac{N^h(x, y, z)/\Delta z}{N^{DIS}(x, y)}
\]

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April 9, 2019
Particle identification uses likelihoods based on the number and distribution of detected photons in RICH associated to a charged particle.

Purity of the charged hadron sample depends on the probabilities $P$ of correct identification and misidentification.

The charged hadron yield is corrected using these probabilities by unfolding:

$$\begin{bmatrix} I_\pi \\ I_K \\ I_p \end{bmatrix} = M^{\pm} \begin{bmatrix} T_\pi \\ T_K \\ T_p \end{bmatrix} = \begin{bmatrix} P(\pi \to \pi) & P(\pi \to K) & P(\pi \to p) \\ P(K \to \pi) & P(K \to K) & P(K \to p) \\ P(p \to \pi) & P(p \to K) & P(p \to p) \end{bmatrix} \begin{bmatrix} T_\pi \\ T_K \\ T_p \end{bmatrix}$$
Correction for the limited geometrical acceptance, reconstruction and detector inefficiencies as well as resolutions.

\[
A(x, y, z) = \frac{M_{\text{rec}}^h}{M_{\text{gen}}^h} = \frac{N_{\text{rec}}^h(x_{\text{rec}}, y_{\text{rec}}, z_{\text{rec}})/N_{\text{DIS}}^\text{rec}(x_{\text{rec}}, y_{\text{rec}})}{N_{\text{gen}}^h(x_{\text{gen}}, y_{\text{gen}}, z_{\text{gen}})/N_{\text{DIS}}^\text{gen}(x_{\text{gen}}, y_{\text{gen}})}
\]

MC technical features:

- Events are generated with the DJANGOH generator (LEPTO + radiative events, SOPHIA for low energy hadronic final state, LUND MODEL, ARIADNE for parton cascade, [http://wwwthep.physik.uni-mainz.de/~hspiesb/djangoh/djangoh.html](http://wwwthep.physik.uni-mainz.de/~hspiesb/djangoh/djangoh.html)).
- JETSET package for parton hadronization with COMPASS high-\(p_T\) tuning.
- Spectrometer simulated using TGEANT based on GEANT4.

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New way of computing radiative corrections including $z$ dependence. Use of the DJANGOH generator to compute $(x,y,z)$ radiative corrections (H. Spiesberger, N. Pierre)

Radiative processes considered:

- Initial and final state radiation
- Vertex correction
- Vacuum polarisation

Correction factors are applied directly to multiplicities:

$$\eta^h(x,y,z) = \frac{N^h_{\text{BORN}}(x,y,z)/N^h_{\text{BORN}+\text{Corrections}}(x,y,z)}{N_{\text{DIS}}(x,y)/N_{\text{DIS}+\text{Corrections}}(x,y)}$$

Corrections going from 0% (low $y$ and low $z$) to 20% (high $y$ and high $z$).
Presence of hadrons from diffractive vector mesons in the data ⇒ No parton hadronization.

Correction factor to the pion and kaon yield is determined using DJANGOH (SIDIS) and HEPGEN++ (Diffractive processes) Monte-Carlo, with each sample normalized using their respective luminosities.

Correction for the number of kaons and the number of DIS events are:

\[ f^K_\Phi(x, y, z) = \frac{N^K_{\Phi,HEPGEN++}(x, y, z)}{N^K_{\Phi,HEPGEN++}(x, y, z) + N^K_{DJANGOH}(x, y, z)} \]

\[ f^{DIS}_\Phi(x, y, z) = \frac{N^{DIS}_{\Phi,HEPGEN++}(x, y, z)}{N^{DIS}_{DJANGOH}(x, y, z) + N^{DIS}_{\rho0,HEPGEN++}(x, y, z) + N^{DIS}_{\Phi,HEPGEN++}(x, y, z)} \]

\[ C^K_{DVM}(x, y, z) = \frac{1 - f^K_\Phi(x, y, z)}{1 - f^{DIS}_\Phi(x, y, z)} \]

The corrections are < 10% in most bins except low x, mid z where it can reach ~ 20%.
**Systematic studies:**
Acceptance: 10%
RICH PID/Efficiency for $K^\pm$: 0.1% (low $y$) - 7% (high $y$)
Diffractive VM correction: 6% max (low $x$, mid $z$)

$x, y, z$ 3D-binning
300 kinematic bins
Strong $z$-dependence

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$x$, $y$, $z$ 3D-binning
300 kinematic bins
Strong $z$-dependence
KAON MULTIPLICITY RESULTS WITHOUT VERTICAL STAGGERING IN Y - $M_K(x,y,z)$

**PRELIMINARY**

Systematic studies:
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- RICH PID/Efficiency for $K^\pm$: 0.1% (low $y$) - 7% (high $y$)
- Diffractive VM correction: 6% max (low $x$, mid $z$)

**COMPASS p DATA 2016**

$K^-$

$x, y, z$ 3D-binning
300 kinematic bins
Strong $z$-dependence

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KAON MULTIPLICITY RESULTS - $M^K(x,z)$

PRELIMINARY

\[ \langle \frac{dM^K(x,y,z)}{dz} \rangle_y = \langle \frac{N^h(x,y,z)/\Delta z}{N^DIS(x,y)} \rangle_y \]

x,z binning (y-averaged)

212 kinematic bins

Strong z-dependance

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\[ \mathcal{M}^{K^+} + \mathcal{M}^{K^-} = \int_{0.2}^{0.85} \left\langle \frac{dM^{K^+}(x, y, z)}{dz} \right\rangle_y dz + \int_{0.2}^{0.85} \left\langle \frac{dM^{K^-}(x, y, z)}{dz} \right\rangle_y dz \]

COMPASS proton preliminary

COMPASS isoscalar (\(^6\)LiD)*
Results of kaon sum for proton target expected to be 5% above our results for isoscalar target from LO estimations (different PDF combinations involved).

"PLB 767 (2017) 133"
Discrepancy with HERMES results for proton target, already seen with results for isoscalar/deuteron target (but perhaps can be explained cf. *M. Stolarski talk*).
Results of kaon ratio for proton target expected to be 10% above our results for isoscalar target from LO estimations (different PDF combinations involved).

N. Pierre - DIS 2019
Discrepancy with HERMES results for proton target, already seen with results for isoscalar/deuteron target (but perhaps can be explained cf. M. Stolarski talk).

N. Pierre - DIS 2019
Charged kaon multiplicities were measured from COMPASS 2016 data with a pure proton $lH_2$ target and 160 GeV $\mu^+$ and $\mu^-$ beam.

Multiplicities were measured in 300 3-D kinematic bins of $x$, $y$ and $z$.

Preliminary proton results agree with COMPASS results with isoscalar $^6LiD$ target.

Large discrepancy with respect to HERMES $K^\pm$ results obtained with a proton target.

Outlook/In progress:
- Finalizing pions, protons.
- Use the full statistic of 2016 and 2017 data (using $\sim 1/4^{th}$ at the moment).
RICH EFFICIENCIES - $K^+$ AND $K^-$

**PRELIMINARY**  COMPASS p DATA 2016

- $P(\pi^+ \rightarrow K^+)$
- $P(K^+ \rightarrow K^+)$
- $P(p \rightarrow K^+)$

**PRELIMINARY**  COMPASS p DATA 2016

- $P(\pi^- \rightarrow K)$
- $P(K \rightarrow K)$
- $P(\bar{p} \rightarrow K)$
PRELIMINARY

COMPASS p DATA 2016

x, y, z 3D-binning
300 kinematic bins
Strong z-dependance