Preliminary Neutral Pion DIS Multiplicity with CLAS12 Data

FF19 - Duke University

Giovanni Angelini (GWU), PhD candidate
Multiplicity: Brief Motivation

CLAS12: Detector Overview

Data Selection

Preliminary analysis Multiplicity vs z

Future plans
Semi Inclusive Deep Inelastic Scattering

**SIDIS:** The four-vector of the measured hadron can give us information on the proton’s structure.

\[ \sigma^{e p \rightarrow e h X} = \sum_{q} DF \otimes \sigma^{e q \rightarrow e q} \otimes FF \]

Structure Function: \( F \propto DF \otimes FF \)

Partonic Distribution Function. Fragmentation Function
Giovanni Angelini

**Multiplicity**

\[ m^h(x, z, dP^2_{hT}, Q^2) = \frac{d\sigma_{SDIS}^h/dx dz dP^2_{hT} dQ^2}{d\sigma_{DIS}/dx dQ^2} \]

**SDIS:**

\[ e(l)P(P) \rightarrow e(l')h(P_h)X \]

**hadron production plane**

\[ P_{hT} = p_\perp + z k_\perp \]

**lepton scattering plane**

**Transfer momentum**

\[ Q^2 = -(l-l')^2 \]

\[ W^2 = (P+q)^2 \]

\[ x = \frac{Q^2}{2P \cdot q} \]

\[ y = \frac{P \cdot q}{P \cdot l} \]

\[ z = \frac{P \cdot P_h}{P \cdot q} \]

\[ \varepsilon = \text{Photon flux ratio (L/T)} \]

**Squared Invariant mass of the final state**

**Quark longitudinal momentum fraction**

**Fractional energy of the virtual photon**

**Final state hadron momentum fraction**
For simple Gaussian distributions in $k_T$ and $p_T$:

$$m_N^h(x, z, P_{hT}^2, Q^2) = \frac{\pi F_{UU,T}(x, z, P_{hT}^2, Q^2) + \pi \epsilon F_{UU,L}(x, z, P_{hT}^2, Q^2)}{F_T(x, Q^2) + \epsilon F_L(x, Q^2)}$$

**Bi-Local Operator**

Non perturbative. Needs to be extracted from the data.

Kinematics factors drops in the ratio. Information on the FF can be extracted from it.
At large $x$ (sea contribution can be neglected) the multiplicity should follow $z$-dependence of FF (after PT integration).

Fragmentation function for $u$ and $d$ quarks are the same at first approximation.

Suppression of spin-dependent fragmentation function for $\pi^0$ since Collins FF has roughly equal magnitude but opposite sign in up and down quarks.

Suppression of higher-twist contributions at larger energy fraction (important at Jlab energy where small $z$ are contaminated by target fragmentation).

Absence of $\rho^0$ production that complicates the interpretation of charged single pion data.

In exclusive production the longitudinal photon contribution is suppressed with respect the transverse photon contribution which is higher twist. This suggest that longitudinal photon contribution to SIDIS will be also suppressed.
CLAS12 Detector Overview

**Forward Detector:**
- Torus magnet
- Drift Chamber system
- Forward ToF System
- LT Cherenkov Counter
- HT Cherenkov Counter
- RICH
- Preshower calorimeter
- E.M. calorimeter (EC)
- Forward Tagger (FD)

**Central Detector:**
- Solenoid magnet
- Barrel Silicon Tracker
- Central Time-of-Flight
- Micromegas
- Neutron detector

Number of readout channels \( \sim 100,000 \)

https://www.jlab.org/Hall-B/clas12-web/
Installation Completed at the end of 2017

Target used: Unpolarized Liquid Hydrogen. Polarized electron beam (85% of polarization) E = 10.6 GeV

\[ L = 10^{35} \text{ cm}^{-2} \text{ s}^{-1} \]

For this analysis: **Forward Detector**

- \( e' \) ID: Track, FTOF, HTTC, PCAL
- \( \gamma \) ID: \( \beta \)
  - PCAL

Very preliminary results based on < 1% of the data collected. The data were processed with a preliminary reconstruction algorithm. The collaboration has improved and updated these algorithms and is processing a large data sample. In the future weeks I will extend this analysis to 10% of RUN- Group A.
Data Selection: Scattered Electron Cuts

**FIDUCIAL CUTS:**
- Electron Ecal X and Y position
  - EC Included
  - EC Excluded
- Electron Cutted Ecal X and Y position
- Electron DC X and Y position
  - DC Included
  - DC Excluded
- All electrons DC X and Y position

**Data Sample:**

- **SIDIS:** $e\, P \rightarrow e'\, \pi^0\, X$
- **DIS:** $e\, P \rightarrow e'\, X$

**Forward Calorimeter sampling fraction for electrons**
Data Selection: Scattered Electron

- $Q^2 > 1 \text{ GeV}^2$
- $W > 2 \text{ GeV}$
- $y < 0.80$

**MC:**

- CLASDIS LUND Generator
  Based on LEPTO-PEPSI

**Hadronization:**

- Lund String Model

**Reconstructed electrons kinematics**
Data vs MC Kinematics

Electron $Q^2$ distribution

Electron $W$ distribution

Electron $x$ distribution

Electron $y$ distribution

Giovanni Angelini
Reconstructed photons

Photon selections

- Photon Energy > 400 MeV
- Photon with angle > 2° with respect to $e'$

Cal. Sector Uniformity

Photons invariant mass for each CLAS sector (Data)

σ = 11.5 MeV
Data divided in z bin (size 0.1)
0.2 < z < 0.9
Each bin has been fitted with: Gauss + Poly 3rd
π0 s obtained from the gaussian integral

Two methods:
- Combination of all photons pair in event
- The 2 most energetic photons of the event

Efficiency w. Acceptance:
π0s reconstructed from MC (within the cuts)

Each bin has been fitted with: Gauss + Poly 3rd
π0 s obtained from the gaussian integral

π0 Reconstruction in Z bins

Efficiency w. Acceptance:
π0s generated (4π)

Graphs showing data for different z bins:
- 0.5 < z < 0.6
- 0.6 < z < 0.7
- 0.7 < z < 0.8

Two methods:
- Combination of all photons pair in event
- The 2 most energetic photons of the event

Statistical uncertainty
Preliminary Neutral Pion Multiplicity ($<1\%$ of the statistic)

- Combinatory
- Statistical uncertainty
- DSS LO
- DSS NLO

No systematics in the plot!
The Z distribution of neutral pion multiplicity look reasonable even if very preliminary data have been used for this analysis.

In the next months the analysis will be done with better quality data and higher statistics. Results will be obtained in multi dimensional bins.

By the end of this year I am planning to conclude this analysis (maybe compare data on deuterium) and analyzed charged pions.