Measurement of $cos(\phi)$ and $cos(2\phi)$ asymmetries with CLAS12 experiment

Mylene Caudron

IJCLab

May 3, 2021

Introduction

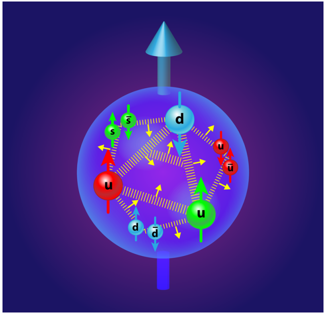


Figure: The inside of a proton

- Proton made of 3 valence quarks
- Each quark has a spin and a momentum
- Study of spin-orbit correlation

  $\rightarrow$ Intrinsic motion of quarks inside the proton

Introduction

- **Transverse Momentum Dependance (TMD)** distribution functions describe the azimuthal distribution of partons inside nucleons.

- **Boer-Mulders function** : generates $cos(2\phi)$ asymmetry in unpolarized leptoproduction, coupled to Collins fragmentation function

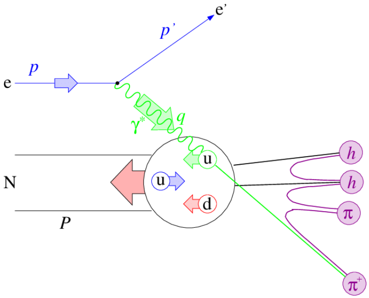
  $\rightarrow$ describe the correlation between the transverse spin and momentum of a quark ejected from an unpolarized target in Semi-Inclusive Deep Inelastic Scattering (SIDIS).

- Goal of this thesis : Measurement of the Boer-Mulders function with CLAS12 experiment

- Extract the $cos(\phi)$ $cos(2\phi)$ asymmetries in unpolarized leptoproduction

Semi Inclusive Deep Inelastic Scattering

We consider the SIDIS reaction : $l(l) + p(P) \rightarrow l'(l') + h(Ph) + X(PX)$



Electron scattered from a proton

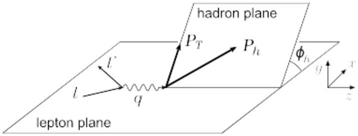
At high enough Q² : scatter from a quark

SIDIS : a hadron is detected with the scattered electron

$\rightarrow$ Here the hadron is a π^+

Semi Inclusive Deep Inelastic Scattering

We consider the SIDIS reaction : $l(l) + p(P) \rightarrow l'(l') + h(Ph) + X(PX)$



$x_B = \frac{Q^2}{2.p.q}$: fraction of the proton momentum carried by the struck quark

$Q^2 = (l^{'} - l)^2$: 4 momentum transfer

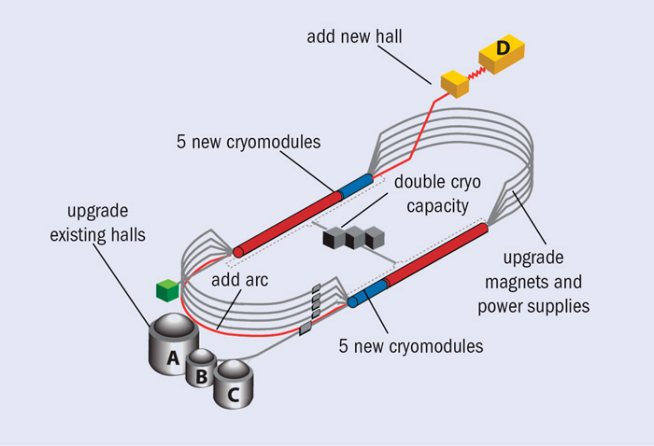
$z = \frac{E_\pi}{\nu}$: fractional energy transfered to hadron

$P_t = \frac{|\vec{p_h} \times \vec{q}|}{|\vec{q}|}$: transverse momentum of hadron

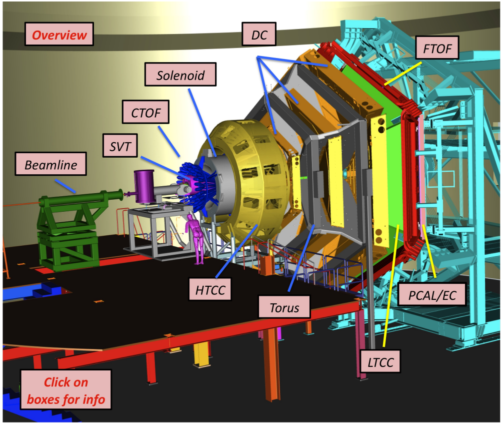
ϕ : azimuthal angle between lepton scattering plane and hadron production plane

Jefferson Laboratory

Jefferson Laboratory in Newport News (VA)
Continuous Electron Beam Accelerator Facility (CEBAF)



CLAS12 Detector



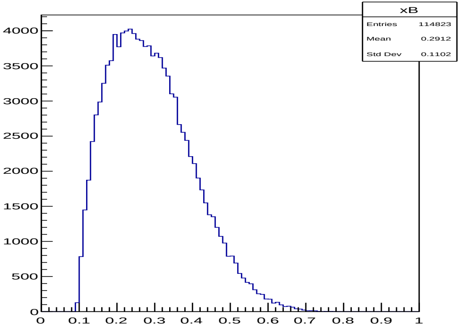
CLAS12 detector (CEBAF Large Acceptance Spectrometer 12 GeV)

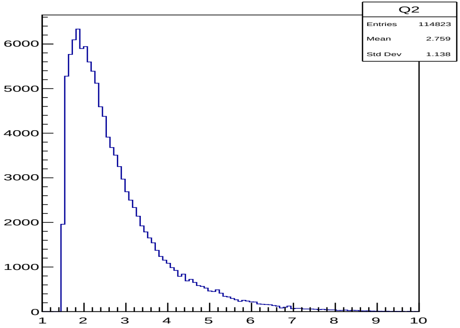
- Cherenkov counters
- EM Calorimeter
- Time of Flight counters
- Tracking

→ Electron beam 10.6 GeV
→ Unpolarized proton target
→ Runs : Fall 2018 and Spring 2019

Kinematic Variables

Kinematic variable for the scattered lepton





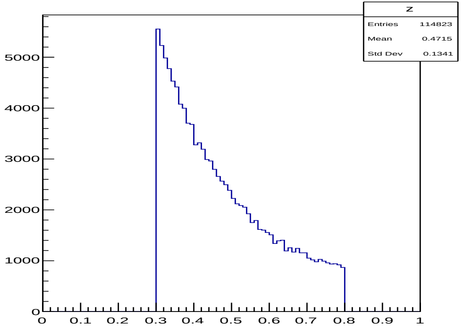
$$x_B = \frac{Q^2}{2.p.q}$$

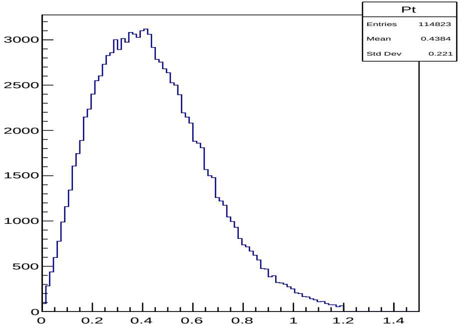
$$Q^2 = (l' - l)^2$$

$$Q^2 > 1.5\,Gev^2$$

Kinematic variables

Kinematic variables for the hadron





$$z = \frac{E_\pi}{\nu}$$

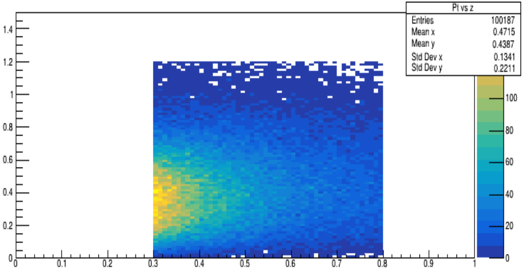
$$0.3 < z < 0.8$$

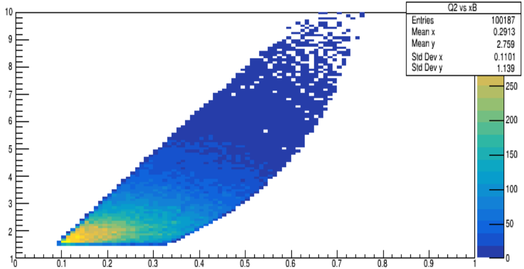
$$P_T = \frac{|\vec{p_h} \times \vec{q}|}{|\vec{q}|}$$

$$P_T < 1.2 GeV$$

Kinematic variables

Correlation between the variables





$\rightarrow$ Strong correlation between xB and Q2 and between Pt and z

Objectives of the analysis

- Extract $cos(\phi)$ and $\cos(2\phi)$ with the asymmetry defined in experiments

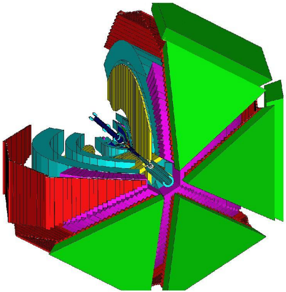
  $$< cos(\phi) >= \frac{\sum cos(\phi)}{N}$$

- Apply corrections (acceptance, radiative...)

  $\rightarrow$ 6 sectors

  $\rightarrow$ Triangular shape

  $\rightarrow$ Big acceptance and radiative effects



Simulations

- SIDIS simulations in CLAS12

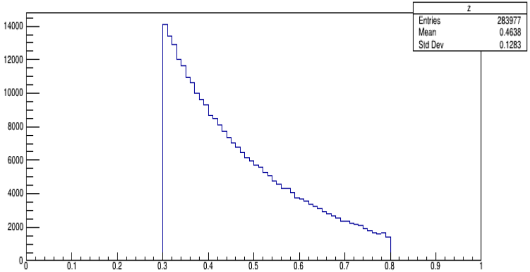
  $\rightarrow$ Simulate the particles through CLAS12 with Pythia event generator and GEMC CLAS simulation

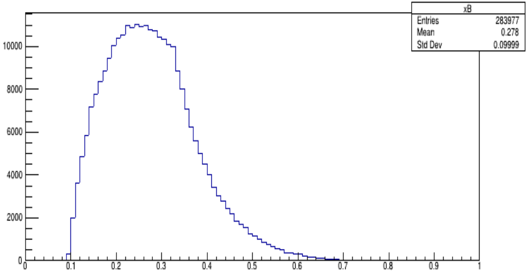
  $\rightarrow$ Extract the data from the generated and the reconstructed particles

- Fit the pion spectrum with the form $A + Bcos(\phi) + Ccos(2\phi)$

- Extract the $cos(\phi)$ and $cos(2\phi)$ asymmetries and conclude on the Boer-Mulders function

Simulation : kinematic variables



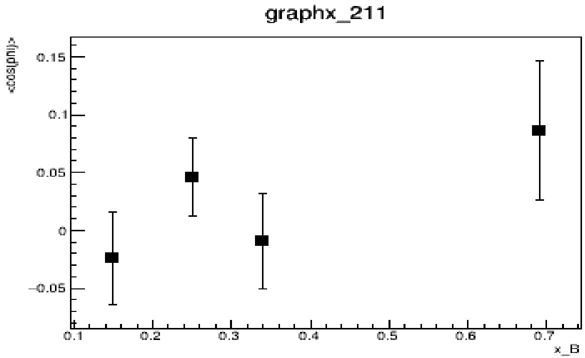


$$z = \frac{E_\pi}{\nu}$$

$$x_B = \frac{Q^2}{2.p.q}$$

Preliminary Results

Preliminary results



⚠ Not really physical results

Need of acceptance correction

cos(ϕ) and *cos*(2ϕ) asymmetries in function of the different kinematic variables

Results and simulation

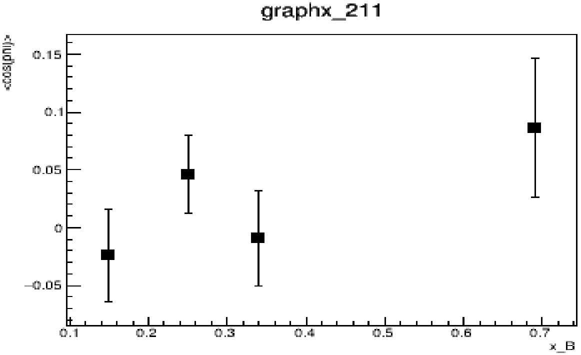


Figure: Data analysis

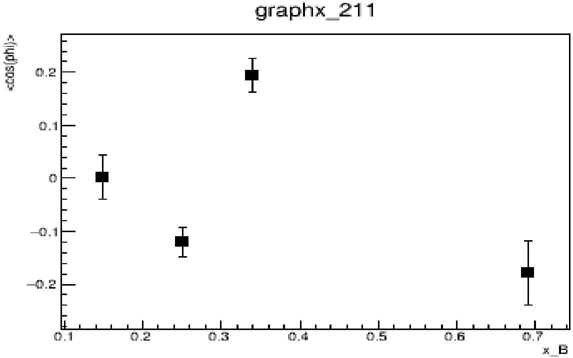
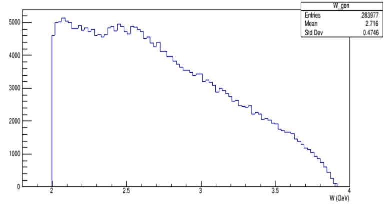
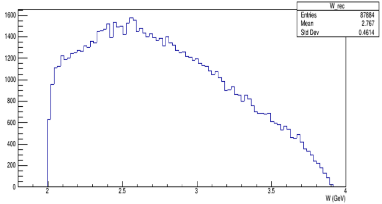


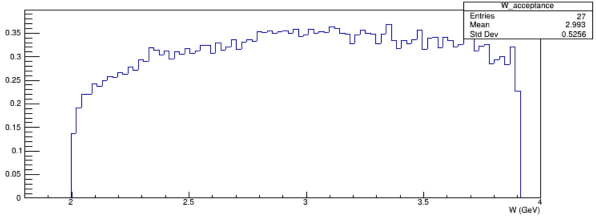
Figure: Simulation

Simulation without ϕ modulations show large asymmetries du to the detector geometry

Results : Acceptance







→ 2/3 of loss

W : invariant mass of hadronic final state

Summary

- What was done

  → extraction of the kinematic variables

  → extraction of the asymmetries from the data

  → analysis of SIDIS simulations and extraction of reconstructed and generated data

  → First step of acceptance correction

- Next steps

  → Extract the acceptance from all the multidimensional bins

  → Apply to the data

  → Radiative correction

  → Systematic error evaluation

Thank You