Charge Symmetric Background Study

For ^{1}H and ^{2}H Inclusive Cross-section Measurement and F2 Structure Function Extraction

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Outline

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F2 Measurement Motivation

What are the Physics motivations?

- Constrain **P**arton **D**istribution **F**unctions **(PDFs)**
- **Resonance** / **DIS** Modelling
- **Quark - Hadron** Duality

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F2 Measurement Motivation

why this work ?

Goal

To study the Charge Symmetric Background (**CSB**) for **HMS 59-degree data**. Which will lead to cross-section measurement and F2 extraction

Basic milestones

1. **Obtaining a working framework**, benchmark by SHMS known results.
2. **Performing CSB study** for the 59 degree HMS.
3. Check for **other corrections**
4. **Obtain** Cross-section and F2

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Background

What is F2?

1. F_2 is a **Nuclear structure function**, which depends on the Bjorken Scaling parameters x and square of momentum transfer Q^2; $F_2(x, Q^2)$[1,2]

2. The F_2 is obtained experimentally from **I**nclusive **S**cattering **R**eactions **cross-section** measurement.

3. Determination of F_2 for ^{1}**H** and ^{2}**D** at the **DIS** and **resonance region**; for a large range of x ($\approx$ **0.2** to **1**) and Q^2 ($\approx$ **4** to **16GeV**), an **inclusive scattering reaction** was used.

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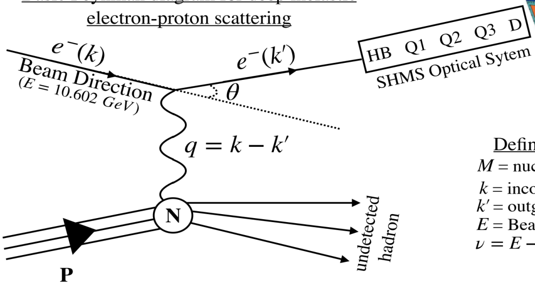
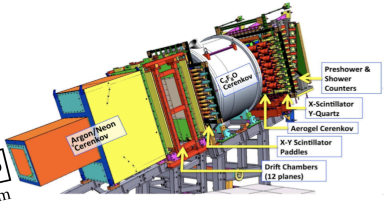
Background

- Targets LH2, LD2, Al

Basic Feynman diagram for deep inelastic electron-proton scattering





Definitions of several kinematic variables

M = nucleon mass

k = incoming electron four momenta

k' = outgoing scattered electron four momenta

E = Beam energy, E' = recoil energy of electron

$\nu = E - E'$ = virtual photon energy

Figure: First order Feynman diagram for electron-nucleon inclusive scattering.

Background

Some definitions of interest:

- Negative squared mass of the virtual photon: $-q^2 = Q^2 = 4EE'Sin^2(\frac{\theta}{2})$
- Virtual photon energy: $\nu = E - E'$
- Bjorken scaling parameters (fraction of the nuclear momentum carried by the struck Parton): $x = \frac{Q^2}{2p.q} = \frac{Q^2}{2M\nu}$
- Fraction of the beam energy transferred by virtual photon: $y = \frac{p.q}{p.k} = \frac{\nu}{E}$
- Invariant mass squared of the final hadronic state: $W^2 = (p+q)^2 = M^2 + 2M\nu - Q^2$

Experiment

Experiment number: E12-10-002

- **Data were obtained** using High Momentum Spectrometer (**HMS**) & SuperHMS (**SHMS**) in **Feb.–March 2018** at Jefferson Lab, using the **10 cm long** liquid ^{1}**H** and ^{2}**H** targets.
- At Beam energy: **10.602 GeV**; Current: between **30** and **65**μA.
- **Acquired data contain Background**: Charge-Symmetric processes are one of the major contributors to the background (**6** to **20%** for (**CSB**) [1])

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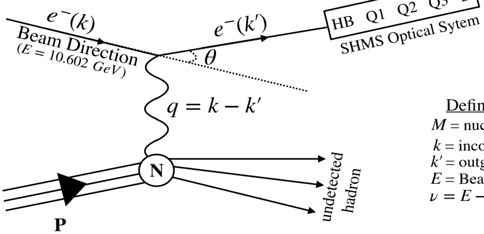
CSB Analysis

- **CS** processes produces **electrons** which are **indistin-guishable** from that of the **scattered electrons**.

- Targets LH2, LD2, Al

<u>Basic Feynman diagram for deep inelastic electron-proton scattering</u>



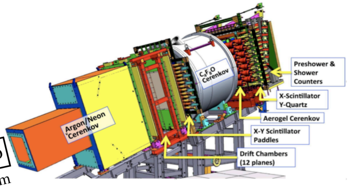


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Figure: First order Feynman diagram for electron-nucleon inclusive scatter

CSB Analysis

- **Neutral Pion Decay** is the major source of **CSB**

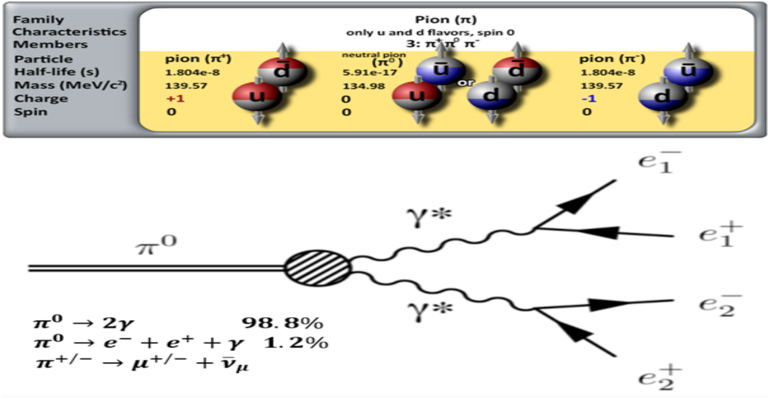

Figure: Pions & Neutral Pion decay channels & branchingratio.

CSB Analysis

- **CS** The process is charge symmetric. By measuring the **e+** counts, the no. of **e**'s produced in the process can be estimated

- **e+ Yield** is measured by changing the polarity of the spectrometer magnet with the same Kinematic settings as that of **e**
- **Positron to electron** (e+/e) ratio is then obtained.

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CSB Analysis

How do one obtain the e+/e from the data ?

Desires variables results

Inputs (target, Spect_Angle, Spectrometer, Cent. Mom.)

Run

$$Y_{corrd} = \frac{Y_{exp} * PC_{\pi}}{\varepsilon_{track} * \varepsilon_{trig} * biol * C_{LT}}$$

After each run: $Y_{Corrd} = Y_{corrd} * PS$. PS is prescale
Sum Over available runs for **e+** or **e**. Then $Y_{Charged\_Norm.} = \frac{Y_{Corrd}}{Charge_{tot.}}$

CSB Analysis

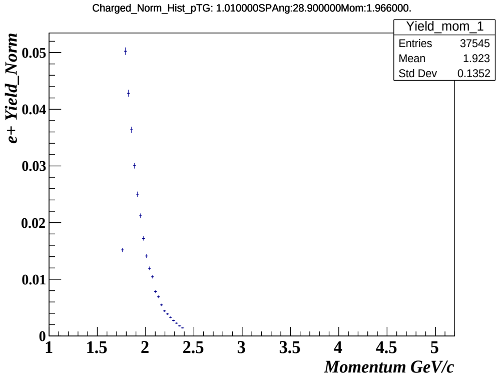

Figure: Positron Charged Normalized Yield for Hydrogen at 29 degree.

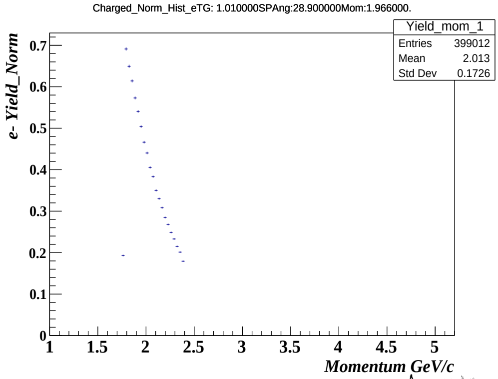

Figure: Electron Charged Normalized Yield for Hydrogen at 29 degree.

CSB Analysis

- The **e+/e** is calculated with:
- $$Y_{corrd} = \frac{Y_{exp}}{C_{LT}}$$
- $$Y_{corrd} = \frac{Y_{exp}}{\varepsilon_{track}}$$
- $$Y_{corrd} = \frac{Y_{exp}}{\varepsilon_{trig}}$$
- $$Y_{corrd} = \frac{Y_{exp}}{biol}$$
- The Computer livetime have the largest contribution

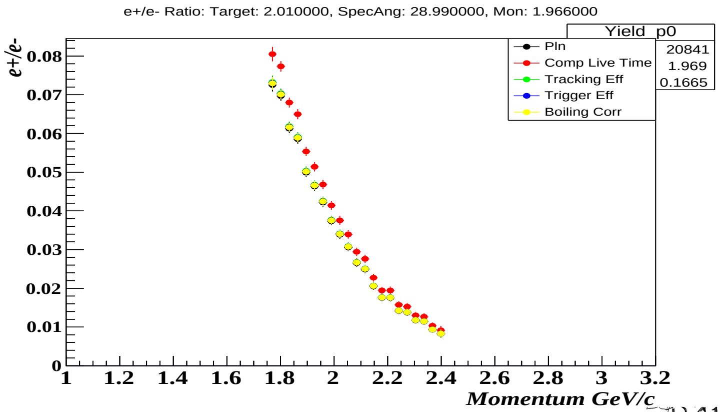

Figure: e^+/e^- Ratio: Corrections placed separately tovisualize their eff

CSB Analysis

- The **e+/e** is calculated with:
- $Y_{corrd} = \frac{Y_{exp}}{C_{LT}}$
- $Y_{corrd} = \frac{Y_{exp}}{C_{LT} * \varepsilon_{track}}$
- $Y_{corrd} = \frac{Y_{exp}}{C_{LT} * \varepsilon_{track} * \varepsilon_{trig}}$
- $Y_{corrd} = \frac{Y_{exp}}{C_{LT} * \varepsilon_{track} * \varepsilon_{trig} * biol}$
- The corrections increases the ratio

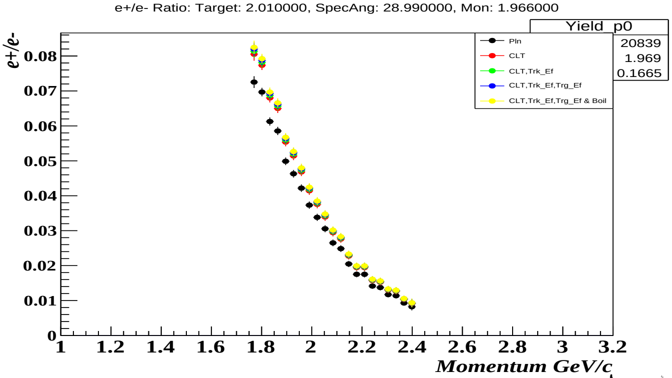

Figure: e^{+}/e^{-} Ratio: Corrections added sequentially to visualize their effects.

CSB Analysis

- The **e+/e** was obtained for different angles **(39,29,21)** and targets **(H, D)**
- $\frac{e^+}{e^-} = \frac{Y_{Charged\_Norm.\_e+}}{Y_{Charged\_Norm.\_e-}}$
- The CSB contribution is seen to be less at smaller angles than in larger angles.

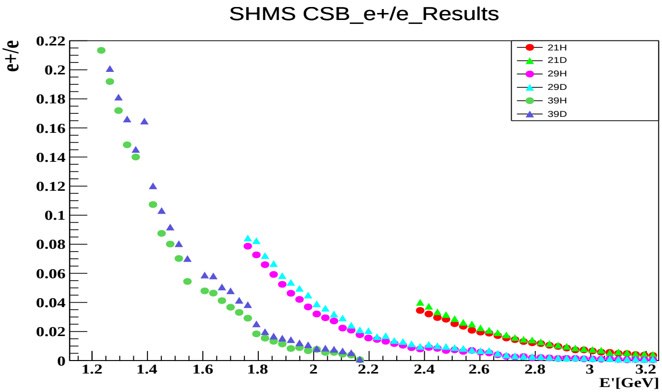

Figure: e^+/e^- Ratio: for different angles. It's more at higher ang

CSB Analysis

- The measured e^- radiative corrected differential cross-section $\frac{d^2\sigma_{e-}}{d\Omega dE'}$ was used with the $\frac{e^+}{e^-}$ yield ratio to give the e^+ x-section as:

- $$\frac{d^2\sigma_{e+}}{d\Omega dE'} = \left(\frac{Y_{e+}}{Y_{e-}}\right)\frac{d^2\sigma_{e-}}{d\Omega dE'}$$

- The result is in agreement with earlier results from JMU.

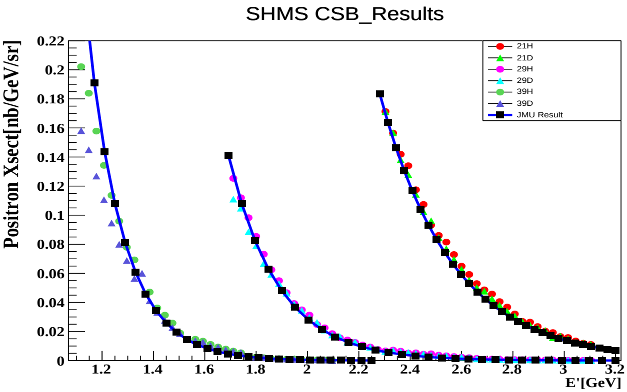

Figure: Positron cross-section. Comparedwith earlier res

CSB Analysis

- Plots were fitted with $\frac{d^2\sigma_{e+}}{d\Omega dE'} = e^{p_0}(e^{p_1(E_b - E')} - 1)$
- $\frac{d^2\sigma_{e+}}{d\Omega dE'}$: plotted differ. Cross-section; E_b, E' beam & scattered e^- energy & p_0, p_1
- **$p_0(\theta)$, $p_1(\theta)$: are used to calculate this effect at other angles (**θ = 25, 33 ^{0}), where e^+ data were not taken due to time constrain.

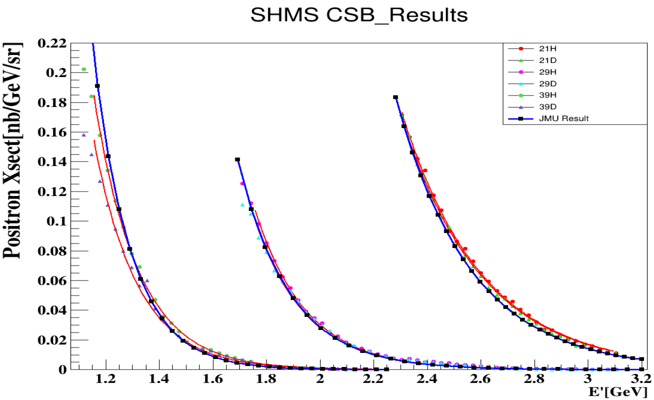

Figure: Positron cross-section with fit perform

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CSB Analysis

	P0	P0 erro	P1	P1 errc	P0 JMU	P1 JMU	% Error P0	% Error P1
H21	-29.3	0.066	3.32	0.008	-31.4	3.57	6.68789808	7.00280112
D21	-29.311	0.064	3.318	0.009	-31.4	3.57	6.65286624	7.05882352
H29	-48.17	0.078	5.193	0.009	-48.2	5.19	0.06224066	-0.0578034
D29	-48.203	0.135	5.19	0.015	-48.2	5.19	-0.0062240	0
H39	-59.284	0.086	6.097	0.009	-69	7.14	14.0811594	14.6078431
D39	-59.371	0.206	6.087	0.022	-69	7.14	13.9550724	14.7478991

$$\delta = \left| \frac{v_A - v_E}{v_E} \right| \cdot 100\%$$

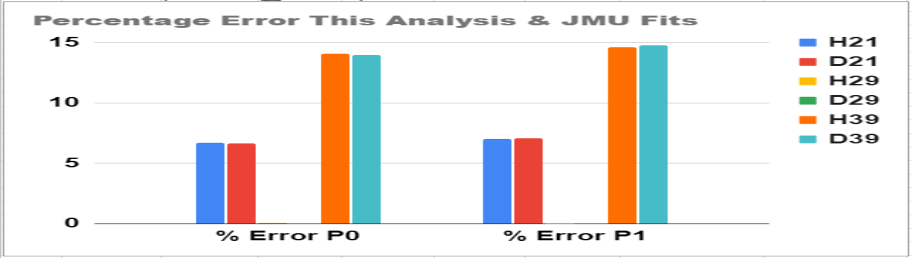

Figure: Basic Error analysis of fitting parameters with earlier results

Conclusion

- **SHMS Charge symmetric background** has been analyzed.
- It has been compared with earlier obtained results.
- The **two results are in good harmony**, with a maximum percentage error of 15% at a spectrometer angle of 39 degrees.
- **The results imply that a framework has been developed** and can be used for other angles analysis.

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Future work

- This work implies that **a framework has been developed** and can be used for the other Spectrometer data analysis from the same experiment.
- The **framework will be used to analyse the HMS data** for a spectrometer angle of 59 degrees.
- The **59-degree data analysis is significant** & the CSB contribution is expected to be high.

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Thank You

References I

1. SP Malace, M Paolone, S Strauch, IM Niculescu, G Niculescu, A Accardi, I Albayrak, O Ates, E Christy, C Jackson, et al. Precision measurements of the f2 structure function at large x in the resonance region and beyond.
2. Debaditya Biswas. Extraction of Proton and Deuteron F 2 Structure Function from Inclusive Electron-Nucleon Scattering at Large Bjorken- X. PhD thesis, Hampton University, 2022.

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