Triple coincidence $A(e,e'pn)$

CLAS data mining analysis

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2nd Workshop on Quantitative Challenges in SRC and EMC Research

March 22, 2019

Massachusetts Institute of Technology
Motivation

Extract missing momentum dependence of the $A(e,e'pn)/A(e,e'p)$ ratio

Compare theory to data

Leading nucleon is a proton

(Good missing momentum resolution)
Neutron Extraction

\[ A(e,e'pn) \]

**TOF counters**

**Advantage:**
Large angular acceptance: 8 – 140 deg

**Disadvantage:**
Low detection efficiency (large correction)

Analysis done by Meytal Duer, \( A(e,e'pn) \)

**Electromagnetic Calorimeter:**

**Advantage:**
Relatively high efficiency

**Disadvantage:**
Can't be used for recoiling neutrons
Selection of neutrons in TOF counters – Veto Algorithm

TOF scintillators response: \textcolor{red}{\textit{Charge}} \approx \textcolor{black}{\textit{Neutral}}

Veto algorithm based on the drift chambers that are sensitive to charged particles.

\textbf{Veto by drift chambers:}

All hits with a corresponding track are charged.
**Problem:** Standard tracking is optimized to remove false positive.

Example for a not reconstructed track:

- Three hits out of 6: superlayer 5
- No hits in superlayer 3

**Solution:** Correlated track even it’s not fully reconstructed.
Neutron candidates after the Veto algorithm

This neutron can be fake neutron
Relatively close to the track
Veto algorithm remove hits due to charged particles

Energy Deposition

Electrons

Protons

Energy Deposition by electrons [MeV]

Energy deposition by protons [MeV]

Charged Particles

Neutron Candidates

Energy Deposition [MeV]
Calibration: Deuteron target

d(e,e'pn)

- Detection efficiency
- Momentum resolution
- Test Veto algorithm

Selection of d(e,e'p)n event
Selection of d(e,e'pn) events

\[ \beta \] — Calculated based on missing momentum assuming a neutron mass

\[ \cos(\vec{p}_m, \vec{p}_n) \]

(Missing Momentum = Initial Momentum)

Corrected TOF

\[ T_{\text{measured}} - \frac{\text{Distance}}{c\beta} \]
Momentum Resolution

Large background at low Missing momentum

\[ \frac{\Delta p}{p} \approx 8\% \]

\[ \chi^2 / \text{ndf} = 69.75 / 47 \]

- Constant: 52.18 ± 3.40
- Mean: 0.0003801 ± 0.0017404
- Sigma: 0.0379 ± 0.0018
Absolute neutron detection efficiency

\[ \eta = \frac{\text{Measured}}{\text{Expected}} = \frac{d(e, e' pn)}{d(e, e' p)} \]

Test veto algorithm

For a given energy deposition and 30 Veto conditions.
Selection of \( A(e,e'p) \) events

Same cuts as for the \( A(e,e'pp) \) analysis

Hen et al., Science 346 (2014)

\[ X_B > 1.2 \]

Leading Proton: \( 0.96 > q/p > 0.62 \) and \( \text{acos}(pq) < 25 \)

Missing Mass < 1.1

300 MeV/c < Missing Momentum < 1 GeV/c
Selection of $A(e,e'pn)$ events

1) $A(e,e'p)$ cuts

2) CLAS fiducial region for neutrons

3) Time of flight

Individual TOF bars seen

Time Window
Estimate BG using out of time window, assuming Poisson statistics

For each bin in the signal region, simulate number of BG events based on the cyan distribution.

Repeat for \( N \) times

Take the average as a number of Netto neutrons
GCF comparisons

\[ \tilde{p}_N = \tilde{p}_i + \tilde{q}, \sqrt{p_N^2 + m_N^2} \]

\[ \tilde{p}_{\text{recoil}} = \sqrt{p_{\text{recoil}}^2 + m_p^2} \]

\[ -\tilde{p}_{\text{cm}, E_{A-2}} = \sqrt{p_{\text{cm}}^2 + (m_{A-2} + E^*)^2} \]
$C(e,e'p)$ quantities (requiring recoil neutron)
Reconstruction of kinematic variables

Counts

Missing momentum [GeV/c]

Opening Angle
$C(e,e'pn)/C(e,e'p)$ Result

*Data is corrected to the neutron detection efficiency

Preliminary

GCF calculations based on AV18

Energy deposition > 7 MeV
(only statistical uncertainties)

Veto sensitivity test

Missing momentum [GeV/c]

Iteration Number
Large energy deposition cut
Uncertainties not weighted yet.

GCF calculations (AV18)
Due to large uncertainties, we can't distinguish between AV18 and N2LO based on (e,e'pn) data.

See Axel talk.
Summary

The measured $C(e,e'pn)/C(e,e'p)$ is consistent with the GCF

$pn$ measurement is less sensitive to the SCX correction

$pp + pn$ pairs up to 750 MeV/c are almost 100%

$pp/np$ is going from ~1/20 to ~1/2

The total number of neutron events is constant:

Hall A: E05-015, carbon target: ~200 neutrons
Hall A: E07-006, He$^4$ target: ~200 neutrons
CLAS6: A($e,e'n$), EC detector: ~200 neutrons
CLAS6: A($e,e'pn$), TOF counters: ~200 neutrons

Hen et al., Science 346 (2014)
Thank you for your attention