Data Mining Project

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CLAS Collaboration meeting

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Outline

1) Motivation
2) Method of identifying neutrons (TOF counters)
3) Calibration with Deuteron
4) Next Steps
Short Range correlation

High energetic projectiles and large momentum transfer reactions probe small distances and disintegrate the SRC pair.

Why going to high missing momentum?

\[ p_{\text{miss}} = p_f - q \]

* Go above mean field region
* Reduce competing processes
* confine FSI between the SRC pairs

| \(|\vec{p}_1|,|\vec{p}_2| > k_F\)
| \(|\vec{p}_1| \approx -|\vec{p}_2|\) | 2N-SRC |
**Indication for SRC**

* Inclusive scattering at SLAC and at JLAB, measured scaling effect at Bjorken $X$

\[ \frac{2}{A} \sigma_F^\text{Fe}(x,Q^2) / \sigma_D(x,Q^2) \]


Inclusive Scattering

K. Sh. Egiyan et al.

K. Sh. Egiyan et al.

N. Fomin et al.,
Exclusive measurements

Direct measurement of 2N-SRC done using

- BNL: $^{12}\text{C}(p,2pn)$
- Jlab (Hall A): $\text{C}(e,e'pN)$
- Jlab (Hall A): $\text{He}(e,e'pN)$
- Jlab (CLAS): $\text{A}(e,e'pp)$ (C, Al, Fe, Pb)

The extracted fractions of np (top) and pp (bottom) SRC pairs. The green and yellow bands reflect 68% and 95% confidence levels, respectively. np-SRC pairs dominate over pp-SRC pairs in all measured nuclei. The figure was adapted from I. Korover, PhysRevLett.113, 022501 (2014) and O. Hen, et al., Science 346, 614 (2014).
A(e,e'pN) analysis done on eg2a run period

Measured

Predicted

np data obtained from (e,e'p) – (e,e'pp)

C. Colle et al.  
Motivation for the current analysis

Extend A(e,e'pn) measurements to heavier nuclei (Fe, Pb).

(Done on He and Carbon only)

Measure the fraction of np – SRC as function of A

Combine with pp-SRC estimate the total amount of 2N-SRC in the nuclei (C, Al, Fe, Pb)
Use of eg2a run period to measure $A(e,e'pn)$.

**Advantages:**

- CLAS: open trigger
- Nuclei, from light $^{12}$C up to $^{208}$Pb
  - Allow to study the np fraction as function of $A$
- Existence of liquid deuterium target
  - Measurement of neutron detection efficiency.
- Large angular coverage
  (Compared to previous experiments)

**Challenges:**

- Low neutron detection efficiency of TOF counters
Data Analysis  Extraction of neutron from eg2a data

Neutron hits in the TOF counters can be extracted from tracking plus SCRC bank data.

**Technical issue:** Current ClasTool does not read SCRC BOS bank.

**Solution:** (1) Implement SCRC in ClasTool, Gagik help.
(2) At this point, we access the bank directly (without ClasTool) to develop analysis methodology until step (1) is done.

The following results are therefore very preliminary.
Information on hits in TOF counters:

- **Sector**: Number of the sector of interest (from 1 to 6)
- **Id**: Paddle number in the sector (from 1 up to 48)
- **Energy**: Energy deposit in MeVee
- **Position**: Hit position in the sector coordinate system.
- **Time**: Timing information

(For absolute time the start time is subtracted)
Cuts for Veto:

1) Neutral hits are defined by requiring no tracks within ±10 cm.

E.S. Smith et al.
"Neutral" hits multiplicity:

Most "neutral" hits are gamma and unreconstructed charged particles.
We aim to study neutrons in momentum range: 300 – 700 MeV/c

Relevant time window 30 – 70 ns

~1.05 hits per event in this time window
Contamination of “neutrals” with unreconstructed charged particles

- Charged Particles
- Electrons
- Protons
Event display Program – CED

From Gn analysis
CLAS analysis Note 2008-103

No hit in the chamber

Candidate for “neutron”

Clearly track due to charged particles.

However, before we include wire data for Veto algorithm improvement, we continue to see how far we can get.
Neutron Calibration with deuteron

Liquid deuterium

Solid Target
Energy deposit $> 5 \text{ MeVee}$

Eliminate contribution from low energy events (low energy photon background)

Compare to the previous analysis done in CLAS
The energy of the neutrons can be determined by the Time-of-flight measurement.

Translation from TOF to momentum

\[ p_n = \frac{m}{\sqrt{\left(\frac{0.3 \cdot t}{d}\right)^2 - 1}} \]

Expected arrival time for Photons
Missing Mass of d(e,e'p)

Missing Mass for d(e,e'p) (Double coincidence events)

- Entries: 43975
- Mean: 0.9926
- RMS: 0.09918
- $\chi^2 / \text{ndf}$: 40.35 / 34
- $p_0$: 846.1 ± 12.7
- $p_1$: 0.947 ± 0.001
- $p_2$: 0.04281 ± 0.00086
- $p_3$: 5.938 ± 0.866
- $p_4$: 4.285 ± 0.147

Large background
Opening Angle

Opening angle between measured neutral hit and expected neutron From d(e,e'pn) reaction.

Energy deposit > 5 MeVee
Missing mass
Opening angle

Energy deposit
Missing Mass
Time Window
30 – 65 ns

Out of time
Corrected TOF

"Corrected" TOF

With Cuts:

Energy deposit
Missing mass
Time Window
Opening angle
Missing Mass for $d(e,e'p) + \text{neutral hit}$

Missing Mass for $d(e,e'p) + \text{neutron hit}$

Cuts:
- Energy deposit
- Missing Mass
- Time Window
- Opening angle

Low Background
Energy Deposit
Missing Mass
Corrected TOF
Angles differences
Reconstructed momentum resolution:

\[ \frac{\Delta p}{p} \approx 10\% \]
Neutron detection efficiency.

Efficiency determined by ratio \[
\frac{\# \text{d(e,e'pn)}}{\# \text{d(e,e'p)}}
\]

Count of \#d(e,e'pn) reaction is straight forward

In \#d(e,e'p) events there is large background

\#d(e,e'p) events above red dash line
Efficiency Results:

Although we did not removed the unreconstructed tracks that mimic neutral hits in the efficiency result is consistent with Gn analysis.
Neutron efficiency: Gn analysis

![Graph showing neutron detection efficiency vs. neutron momentum for 4.2 GeV, 2.6 GeV, and 5.014 GeV data points. The graph includes error bars and labels indicating preliminary data.]
Future plans:

1) Modify ClasTool to extract the TOF counters hits
2) Extract the wires hit data from dc0 BOS bank – improve Veto algorithm
3) Redo deuteron calibration
4) Extract the number of $A(e,e'pn)$ events from the solid targets
5) Extract the ratio $A(e,e'pn)/C(e,e'pn)$ (no absolute neutron detection efficiency needed)
6) Measure $A(e,e'pn)/A(e,e'p)$ (neutron detection efficiency needed)
7) Measure the CM momentum of the 2N- SRC
8) More physics … :)

## Collaborators

<table>
<thead>
<tr>
<th></th>
<th>Tel Aviv University</th>
<th>MIT</th>
<th>ODU</th>
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<tbody>
<tr>
<td>Meytal Duer</td>
<td></td>
<td>Or Hen</td>
<td>Larry Weinstein</td>
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<tr>
<td>Erez Cohen</td>
<td></td>
<td>Shalev Gilad</td>
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<tr>
<td>Adi Ashkenazi</td>
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<td>Eli Piasetzky</td>
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</table>
Thank you
Energy deposit

Time window: 30 – 70 ns

Time Window for gamma:
Neutron calibration

1) Develop method for neutron extraction
2) Identify neutrons from d(e,e'pn) reaction in the TOF counters
3) Measure absolute neutron detection efficiency
Data Analysis  Extraction of neutron from eg2a data

Cooked data does not include neutron hits in the SCPB BOS bank, however raw hits data is stored in SCRC BOS bank.

<table>
<thead>
<tr>
<th>Group: SCRC</th>
<th>Sector: 1</th>
<th>Nhits: 3</th>
<th>Next ind: 1838</th>
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</thead>
<tbody>
<tr>
<td><strong>id</strong>: 22</td>
<td><strong>energy</strong>: 1.448</td>
<td><strong>time</strong>: 55.544</td>
<td><strong>pos &gt;x</strong>: 366.114655, <strong>y</strong>: -2.500206, <strong>z</strong>: 376.719238</td>
</tr>
<tr>
<td><strong>err &gt; x</strong>: 0.000000, <strong>y</strong>: 103.992226, <strong>z</strong>: 0.000000</td>
<td><strong>status</strong>: 3</td>
<td><strong>denergy</strong>: 0.000</td>
<td><strong>dtime</strong>: 6.454</td>
</tr>
<tr>
<td><strong>id</strong>: 30</td>
<td><strong>energy</strong>: 1.561</td>
<td><strong>time</strong>: 100.272</td>
<td><strong>pos &gt;x</strong>: 412.525085, <strong>y</strong>: 184.872711, <strong>z</strong>: 217.826065</td>
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<tr>
<td><strong>err &gt; x</strong>: 0.000000, <strong>y</strong>: 23.329113, <strong>z</strong>: 0.000000</td>
<td><strong>status</strong>: 11</td>
<td><strong>denergy</strong>: 0.241</td>
<td><strong>dtime</strong>: 1.408</td>
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<td><strong>id</strong>: 40</td>
<td><strong>energy</strong>: 1.399</td>
<td><strong>time</strong>: 1.358</td>
<td><strong>pos &gt;x</strong>: 411.805756, <strong>y</strong>: 6.217634, <strong>z</strong>: -6.877030</td>
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<tr>
<td><strong>err &gt; x</strong>: 0.000000, <strong>y</strong>: 50.179745, <strong>z</strong>: 0.000000</td>
<td><strong>status</strong>: 11</td>
<td><strong>denergy</strong>: 0.185</td>
<td><strong>dtime</strong>: 3.034</td>
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</table>
Synchronizing tracking data with the SCRC bank

In order to synchronize the TOF hits with the EVNT bank information

HEAD BOS bank

Group: HEAD  Sector: 0  Nhits: 1  Next ind: 0
Version: 0
Run: 42011
Event: 58
Type: 1 (physics data)
ROC: 0
CLASS: 3
Trgbit: 0xc004
TIME: Thu Feb 26 22:18:08 2004
For each event we have multiple hits in each sector.
Definition of neutral hits in TOF counters

We define hit in TOF counter to be a neutral hit if there is no track in the drift chambers.

Each track is stored in the DCPB BOS bank and have hit position in TOF counter.

Group: DCPB  Sector: 0  Nhits: 3  Next ind: 0


ScTr: 202  x_SC: 326.264  y_SC: 107.564  z_SC: -196.830  CX_SC: 0.792  CY_SC: 0.276  CZ_SC: -0.544  X_EC: -0.662  Y_EC: 0.149  Z_EC: -33.423  Th_CC: 1.358  Chi2: 2.723  Status: 2


ScTr : 100*sector+track_ID in *BTR
Position: x_SC, y_SC, z_SC (given in sector coordinate system)