Final Report: Short Distance Structure of Nuclei Mining the Wealth of Existing Jefferson Lab Data

submitted to the

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Contents

I. EXECUTIVE SUMMARY

Over the last fifteen years of operation, the Jefferson Lab CLAS Collaboration has performed many experiments using nuclear targets. Because the CLAS detector has a very large acceptance and because it used a very open (i.e., nonspecific) trigger, there is a vast amount of data on many different reaction channels yet to be analyzed.

The goal of the Jefferson Lab Nuclear Data Mining grant was to (1) collect the data from nuclear target experiments using the CLAS detector, (2) collect the associated cuts and corrections used to analyze that data, (3) provide non-expert users with a software environment for easy analysis of the data, and (4) to search for interesting reaction signatures in the data.

We formed the Jefferson Lab Nuclear Data Mining collaboration under the auspices of this grant. The collaboration successfully carried out all of our goals. Dr. Gavalian, the data mining scientist, created a remarkably user-friendly web-based interface to enable easy analysis of the nuclear-target data by non-experts. Data from many of the CLAS nuclear target experiments has been made available on servers at Old Dominion University. Many of the associated cuts and corrections have been incorporated into the data mining software. The data mining collaboration was extraordinarily successful in finding interesting reaction signatures in the data. Our paper Momentum sharing in imbalanced Fermi systems was published in Science. Several analyses of CLAS data are continuing and will result in papers after the end of the grant period. We have held several analysis workshops and have given many invited talks at international conferences and workshops related to the data mining initiative.

Our initiative to maximize the impact of data collected with CLAS in the 6-GeV era was very successful. During the hiatus between the end of 6-GeV experiments and the beginning of 12-GeV experiments, our collaboration and the physics community at large benefited tremendously from the Jefferson Lab Nuclear Data Mining effort.

II. THE DATA MINING SOFTWARE

A. Introduction

As stated in the introduction, the goal of the Jefferson Lab Nuclear Data Mining collaboration was to (1) collect the data from nuclear target experiments using the CLAS detector, (2) collect the associated cuts and corrections used to analyze that data, (3) provide non-expert users with a software environment for easy analysis of the data, and (4) to search for interesting reaction signatures in the data.

We collected the processed nuclear-target experiment data. This data contains particle momenta, positions, and detector energies and times. However, it still needs a multitude of experiment-specific cuts and corrections. Therefore we also collected these cuts and corrections. We assembled the data and its associated cuts and corrections and made it available through a single web-based interface. This allows the data miners to analyze data without needing to know the intricate details of which specific data set they are analyzing, which specific momentum correction to apply, and which specific fiducial cut to use. Merely by specifying the desired beam energy the desired target and the standard cuts and corrections, the non-expert user can analyze the data. Expert users can implement their own analysis routines within the analysis framework.

This software framework is also ideal for data archiving, preserving the CLAS nuclear target data for future research. This framework is being extended and modified for use with the 12 GeV Jefferson Lab data.

The data is stored on the ODU computer cluster. The analysis services run on the same cluster and are accessible from anywhere in the world via the internet.

B. CLARA Distributed Computing Service

We are using the CLARA service oriented framework for our software framework. CLARA is being developed at JLab for distributed cloud computing. The CLARA framework is a public subscription platform that allows service programs to communicate through the platform using a common interface. A "service" is a user program that can run either on the same host as the platform or elsewhere, provided that the appropriate communication ports are open. Services are pieces of code that perform a specific task, such as momentum corrections for a given data set. Several services can be linked in a chain to perform analysis of the data. The flow of the analysis is provided by the user program.

C. Data Storage and Availability

Data from several experiments are collected, converted to EVIO and catalogued on ODU servers. The user can access data from anywhere in the world by specifying the desired beam energy, target and beam intensity, rather than needing to know the details about the specific experiments. Existing functions for particle identification, momentum and other corrections, and fiducial and other cuts are being implemented for each data set. Note that these functions come from prior analyses which have already undergone the stringent CLAS analysis review process and are therefore preapproved.

Physicists new to CLAS or new to a particular CLAS experiment can just specify that they want to use the standard pre-approved functions for the data set or sets that they are analysing. More experienced analyzers can easily implement new algorithms for particle identification, cuts and corrections.

We developed a plugin driven framework to allow users to implement their own extensions (subroutines or algorithms). Initially, the framework contains extensions that allow the user construct variables (such as Q^2 and p_{miss}) from particle 4-vectors using several predefined functions commonly used in high energy physics.

Data can be analyzed in several different modes.

- Data Skimming - download skimmed event data for the specified beam energy, target and final state particles.
- Computed Physics Variables - download partially processed event data.
- Histograms - process the data on the ODU server and download the final histograms.

1. Data Structure

Due to the distributed nature of the data mining software a new format was needed to store the physics data. Distributed multi-process cloud computing requires some features lacking in existing CLAS data formats.

Future CLAS experiments plan to use the EVIO data format, which was developed by the JLab software group. EVIO lacked some important features necessary for it to be used in the data mining project. New features were implemented specifically to meet the needs of multi-process distributed computing. Since EVIO also provides a native JAVA interface, the data was reformatted from previous data structures to EVIO. Previously used dictionary driven data structures were programmed in JAVA and were packed in EVIO format.

Special software was developed to provide data compression while storing in EVIO (EVIO data API does not provide native data compression), and as a result we reduced the stored data size by 40%, allowing us to store more data on the ODU servers.

Experiment	Target	Beam Energy	Cuts&Corrections
eg2	$^{12}C/^{2}H$	5.0 GeV	YES
eg2	$^{56}Fe/^{2}H$	5.0 GeV	YES
eg2	$^{82}Pb/^{2}H$	5.0 GeV	YES
e2	^{3}He	4.7 GeV	YES
e2	^{3}He	0.9 GeV	YES
eg6	^{2}H	5.7 GeV	NO

TABLE I: Available data on ODU cluster.

2. Data Storage

The data from the CLAS nuclear-target experiments is stored on network disks at Old Dominion University (ODU). The data is converted from the standard CLAS data format into EVIO format and indexed by experiment and run conditions. The eg2, e6 and most of the e2b data sets have been converted to EVIO format and are accessible for use. The associated cuts and corrections for the eg2 and e2b data sets are implemented. See Table I for details.

The data (with instructions for using it) can be found at https://clasweb.jlab.org/wiki/index.php/Nuclear_Data_Mining .

III. DATA MINING ANALYSES

A. Momentum sharing in imbalanced Fermi systems

The atomic nucleus is composed of two different kinds of fermions: protons and neutrons. If the protons and neutrons did not interact, the Pauli exclusion principle would force the majority of fermions (usually neutrons) to have a higher average momentum. Our high-energy electron-scattering measurements using 12C, 27Al, 56Fe, and 208Pb targets show that even in heavy, neutron-rich nuclei, short-range interactions between the fermions form correlated high-momentum neutron-proton pairs. Thus, in neutron-rich nuclei, protons have a greater probability than neutrons to have momentum greater than the Fermi momentum. This finding has implications ranging from nuclear few-body systems to neutron stars and may also be observable experimentally in two-spinstate, ultracold atomic gas systems.

In this work we use the $A(e,e'p)$ and $A(e,e'pp)$ reactions to identify, and characterize,

ppSRC states in ^{12}C, ^{27}Al, ^{56}Fe, and ^{208}Pb nuclei using the Jefferson Lab Hall-B EG2 data set. We require $Q^2 > 1.5$ GeV^2, $x_B > 1.2$, and $|P_{miss}| > 300$ MeV/c. Under these kinematical conditions competing effects such as Meson Exchange Currents (MEC) and Isobar Configurations (IC) are suppressed and Final State Interactions (FSI) should be confined to within the pair itself.

Figure 1 shows the extracted fractions of *np* and *pp* SRC pairs from the sum of *pp* and *np* pairs in nuclei, including all statistical, systematic, and model uncertainties. Our measurements are not sensitive to neutron-neutron SRC pairs. However, by a simple combinatoric argument, even in 208Pb these would be only $(N/Z)^2 2$ 2 times the number of *pp* pairs. Thus, *np*-SRC pairs dominate in all measured nuclei, including neutron-rich imbalanced ones.

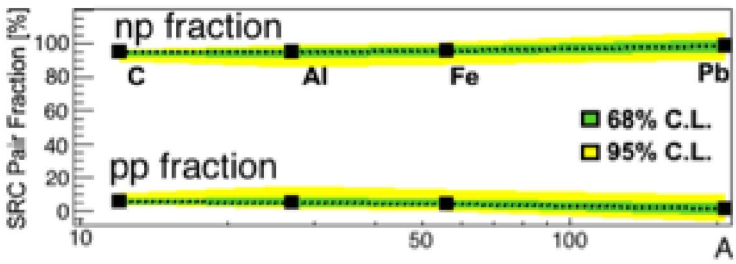

FIG. 1: The extracted fractions of *np* (top) and *pp* (bottom) SRC pairs from the sum of *pp* and *np* pairs in nuclei. The green and yellow bands reflect the 68 and 95% confidence levels, repectively. *np*-pairs dominate over *pp* pairs in all measured nuclei.

The observed dominance of *np*- over *pp*-pairs implies that even in heavy nuclei, SRC pairs are dominantly in a spin-triplet state (spin 1, isospin 0), a consequence of the tensor part of the nucleon-nucleon interaction. It also implies that there are as many high-momentum protons as neutrons so that the fraction of protons above the Fermi momentum is greater than that of neutrons in neutron-rich nuclei.

These results were published in Science [1].

B. Relative Nuclear Transparency of Protons

Nuclear transparency, $T_p(A)$, is a measure of the average probability for a struck proton to escape the nucleus without significant reinteraction. Previously, nuclear transparencies were extracted for quasi-elastic $A(e, ep)$ knockout of protons with momentum below the Fermi momentum, where the spectral functions are well known. We extracted a novel observable, the transparency ratio, $T_p(A)/T_p(^{12}\text{C})$, for knockout of high-missing-momentum protons from the breakup of short-range correlated pairs (2N-SRC) in Al, Fe and Pb nuclei relative to C. The ratios were measured at momentum transfer $Q^2 \geq 1.5$

(GeV/c)^2 and $x_B \geq 1.2$ where the reaction is expected to be dominated by electron scattering from 2N-SRC. The transparency ratios of the knocked-out protons coming from 2N-SRC breakup are 20-30% lower than those of previous results for low missing momentum (see Fig. 2). They agree with Glauber calculations and agree with renormalization of the previously published transparencies as proposed by recent theoretical investigations. The new transparencies scale as $A^{1/3}$, which is consistent with dominance of scattering from nucleons at the nuclear surface.

This analysis was performed by O. Hen under the supervision of E. Piasetzky and L. Weinstein. The results were published in Physics Letters B [2].

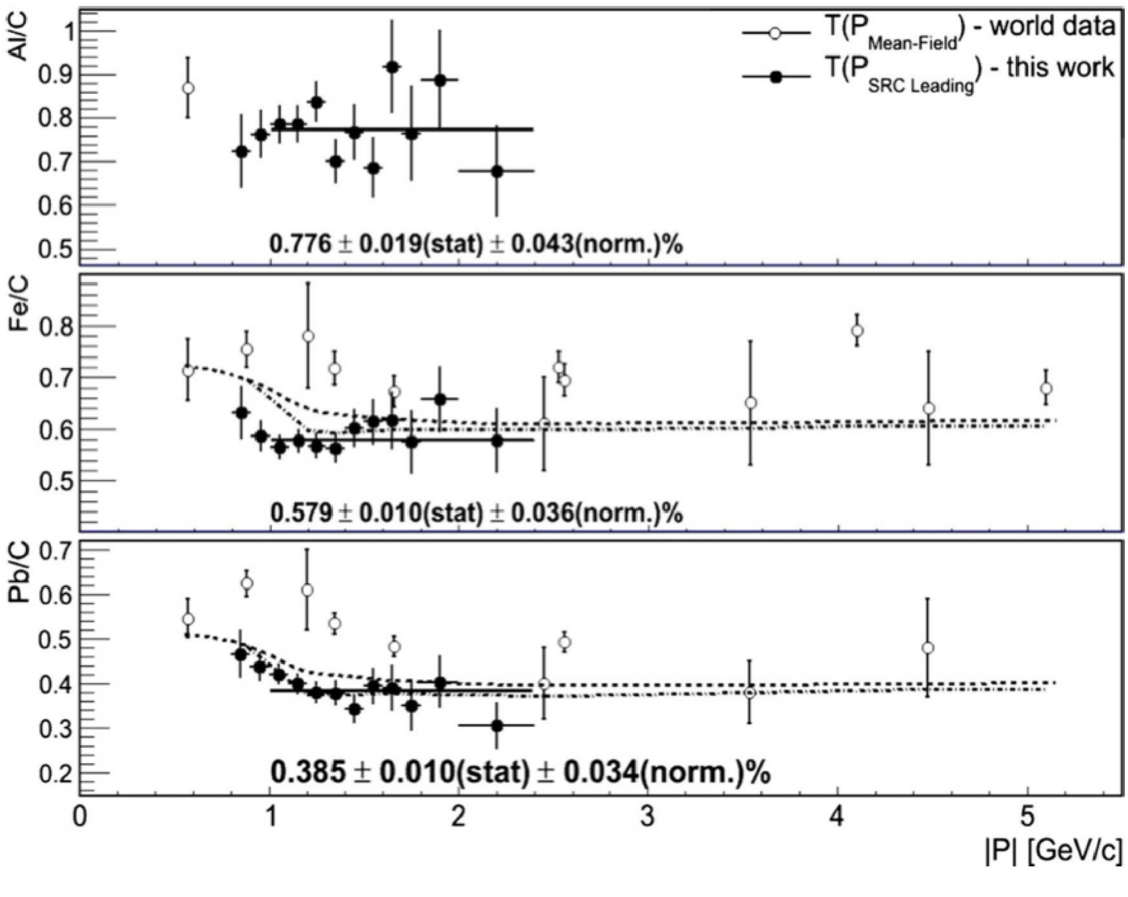

FIG. 2: The measured transparency ratios for various nuclei with respect to carbon of protons from 2N-SRC pairs (full circles) shown as a function of the outgoing proton momentum. The horizontal error bars represent the integration region (bin widths). The solid line is the average transparency and the values are shown. The normalization uncertainty is dominated by the uncertainties in the SRC scaling factors. Also shown for comparison are the world data for transparency ratios for mean-field proton knockout (empty circles), extending up to a proton momenta of 5 GeV/c. Over the momentum range covered by this experiment, the transparency ratios of protons from 2N-SRC are lower than those of mean-field protons by 20-30%. Glauber calculations are shown as dashed lines and dash-dotted lines. See Ref. [2] and references therein.

C. Beam-Target Double Spin Asymmetry in $\vec{D}(\vec{e}, e'p)n$

One of the most promising approaches to understanding the origin of nucleon structure modifications in a nucleus tags the electron scattering process with a spectator nucleon emitted in coincidence (see [3] and elsewhere in this report). The same technique can also be applied to minimize nuclear binding effects and therefore extract the "nearly free" neutron structure functions from measurements on the deuteron [4]. However, the information extracted must be corrected for final-state interactions (FSI) between the struck nucleon and the putative spectator. State-of-the art calculations of FSI are becoming available from our collaborators on the data mining project [5, 6].

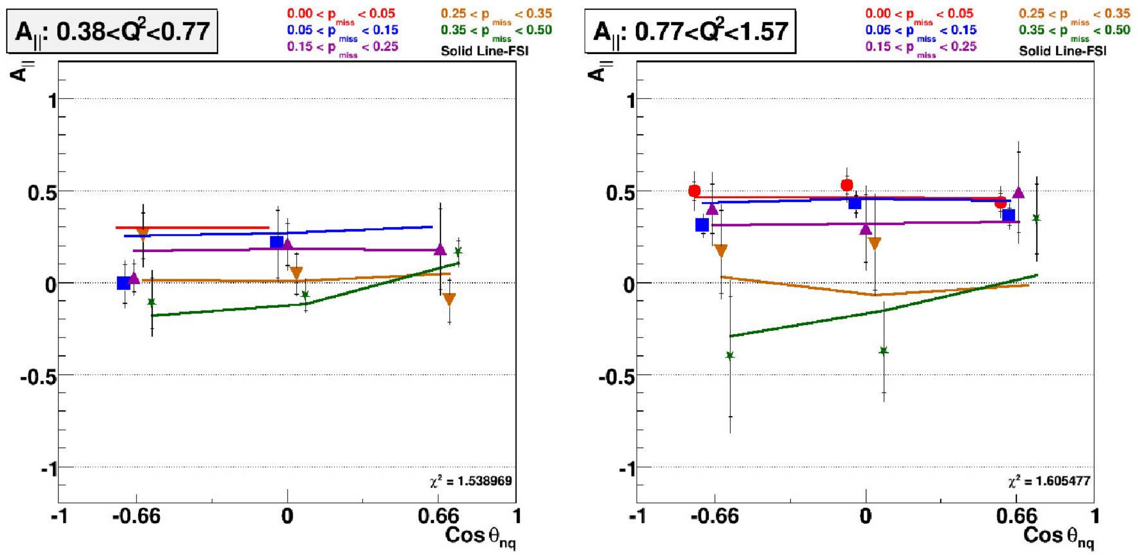

FIG. 3: $A_{||}$ for two Q^2 bins, measured with a beam energy of 2.5 GeV.

To test and benchmark these calculations, we studied the quasi-elastic reaction $\vec{D}(\vec{e}, e'p)n$ where recent calculations both with and without FSI, including both relativity and spin effects, exist [6]. We extracted the double-spin asymmetry, $A_{||}$, for quasi-elastic electron scattering off the deuteron by using existing data from the EG1b experiment. The EG1b experiment scattered longitudinally polarized electrons from 1.6 to 5.8 GeV off a longitudinally polarized cryogenic $^{15}ND_3$ target. $A_{||}$ was extracted from the data as a function of photon virtuality for $0.14 \leq Q^2 \leq 3.17$ (GeV/c)^2, missing momentum for $0.0 \leq p_{miss} \leq 0.5$ GeV/c, and $\cos\theta_{nq}$, the angle between the (inferred) "spectator" neutron and the momentum transfer direction. The extracted values of $A_{||}$ were then compared to the theoretical model with and without the inclusion of FSIs.

Figure 3 shows some of the $A_{||}$ measurements compared to the theoretical model that includes FSIs. While the effect of FSI is small at low missing momenta ($p_s < 0.35$ GeV/c), one can see a marked dependence on $\cos(\theta_{nq})$ for the highest missing momentum bin, clearly born out by the data (without including FSI in the calculations, the χ^2 per degree of freedom is 5.4 and 2.2 for the two Q^2 bins shown, respectively).

This analysis is now complete, and a publication is under CLAS collaboration review. ODU student Michael Mayer has received his Ph.D. on May 11, 2013, based on this analysis.

D. Study of the EMC effect by tagging high momentum recoiling protons

The EMC effect is the observed reduction of the per-nucleon Deep Inelastic Scattering (DIS) cross section ratio in nuclei relative to deuterium. While over 1000 theoretical papers were written in an attempt to explain the effect, there are no theoretical models available that fully explain the EMC effect.

Inclusive quasielastic (QE) electron scattering at large Q^2 and $1 < x_B < 2$ is known to be sensitive to Two Nucleon Short Range Correlations (2N-SRC) [7]. The per-nucleon cross section ratio of nuclei relative to deuterium was shown to scale for $x_B > 1.4$, with the scale factor usually interpreted as a measure of the relative amount of 2N-SRC pairs in the measured nuclei.

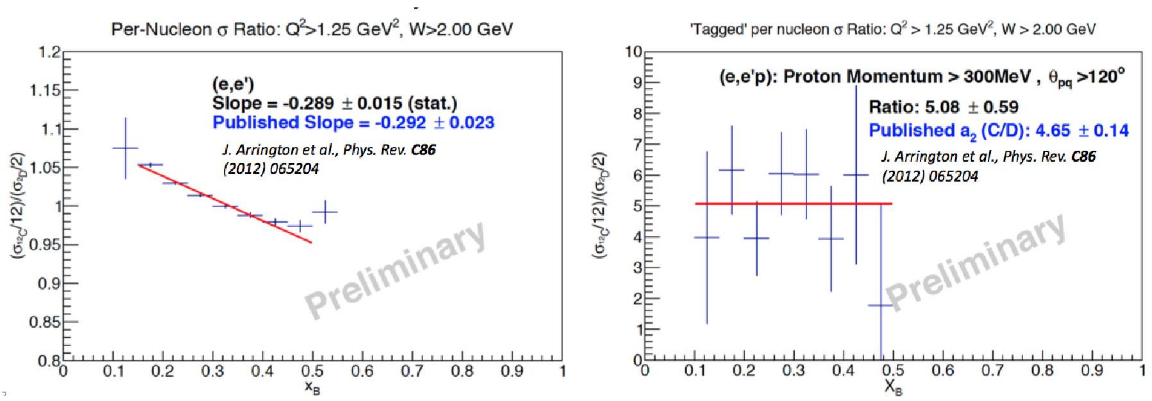

FIG. 4: Preliminary. The EMC ratio for C relative to deuterium for $Q^2 > 1.25$ GeV^2 and $W > 2$ GeV. Left: inclusive (untagged) and Right: tagged on a backward going proton.

Recent global analysis of EMC ($x_B < 1$) and QE ($x_B > 1$) cross section ratios of nuclei relative to deuterium showed that the strength of the EMC effect in nuclei (defined as the slope of the cross section ratio for $0.3 < x_B < 0.7$) is linearly related to the relative amount of 2N-SRC pairs in nuclei [8, 9]. The linearity of this EMC-SRC correlation, and the wide range of nuclei spanned (from ^3He to ^{197}Au) strongly implies that both the EMC effect and 2N-SRC are related to high momentum nucleons in nuclei.

We are studying this correlation by tagging the EMC effect with high momentum recoil nucleons. The most likely way to produce a high-momentum ($p > 0.3$ GeV/c) backward-going nucleon is for the electron to scatter from its correlated forward-going partner. If the EMC effect is related to high momentum nucleons in nuclei, then by tagging on a fast backward nucleon we are requiring the deep inelastic scattering to take place on a high momentum nucleon in both nucleus A and in deuterium. If so, then the tagged EMC cross section ratio should be flat and scale like the relative amount of 2N-SRC pairs in nuclei.

This analysis is being performed by Barak Schmookler under the supervision of Shalev Gilad. He used the data mining software to skim the data and to apply fiducial cuts and vertex corrections. Fig 4 shows preliminary results for the EMC effect in ^{56}Fe from the eg2 data set. The inclusive EMC measurement agrees with previous results. The tagged EMC measurement shows a flat plateau with a height that is consistent with the relative number of SRC pairs in carbon and deuterium.

E. Deltas in the Deuteron

We analyzed $d(e, e'pp\pi^-)\pi^0$ and $d(e, e'p\pi^+\pi^-)n$ events to look for $\Delta(1232)$ knockout from deuterium in the EG2 data set. We hope to place limits on the amount of preexisting Δs in the deuteron in order to understand the role of quark-gluon degrees of freedom in the short range structure of nuclei.

A first analysis by graduate students Uttar Pudaisini and Mahmoud Kamel of Old Dominion University in summer 2012 did not find clear evidence of $\Delta\Delta$ events. A second analysis by C. Wooten for his undergraduate BS thesis looked at $d(e, e'p\pi^+\pi^-)n$ events. He required a proton-virtual photon invariant mass $W > 1.7$ GeV so that the nucleon-pion invariant masses were not overly restricted by phase space. The mass of the proton-π^+ system was cleanly peaked at the Δ mass. He further required that the neutron momentum $p_n > 0.15$ GeV/c to remove two-pion production events on the proton where the neutron was a spectator. Lastly, he required a large rapidity gap between the proton-π^+ system and the neutron-π^- system so that the two systems were unambiguously separated.

Figure 5 shows the rapidity gap plotted versus the $n\pi^-$ invariant mass, the invariant masses of the $n\pi^-$ and $p\pi^+$ systems after the invariant mass cut, and the angular distribution of the $n\pi^-$ system with respect to the momentum transfer. Both the $n\pi^-$ and $p\pi^+$ systems show a clear peak at the Δ mass. The $n\pi^-$ system is emitted at 180° with respect to the momentum transfer, a typical signature for the knockout of a preexisting (spectator) particle. Further analysis and theoretical calculations will be needed to make a quantitative statement about preexisting $\Delta\Delta$ components in the deuteron.

This channel was also analyzed by Andrew MacClintock for his ODU BS thesis (Dec 2013).

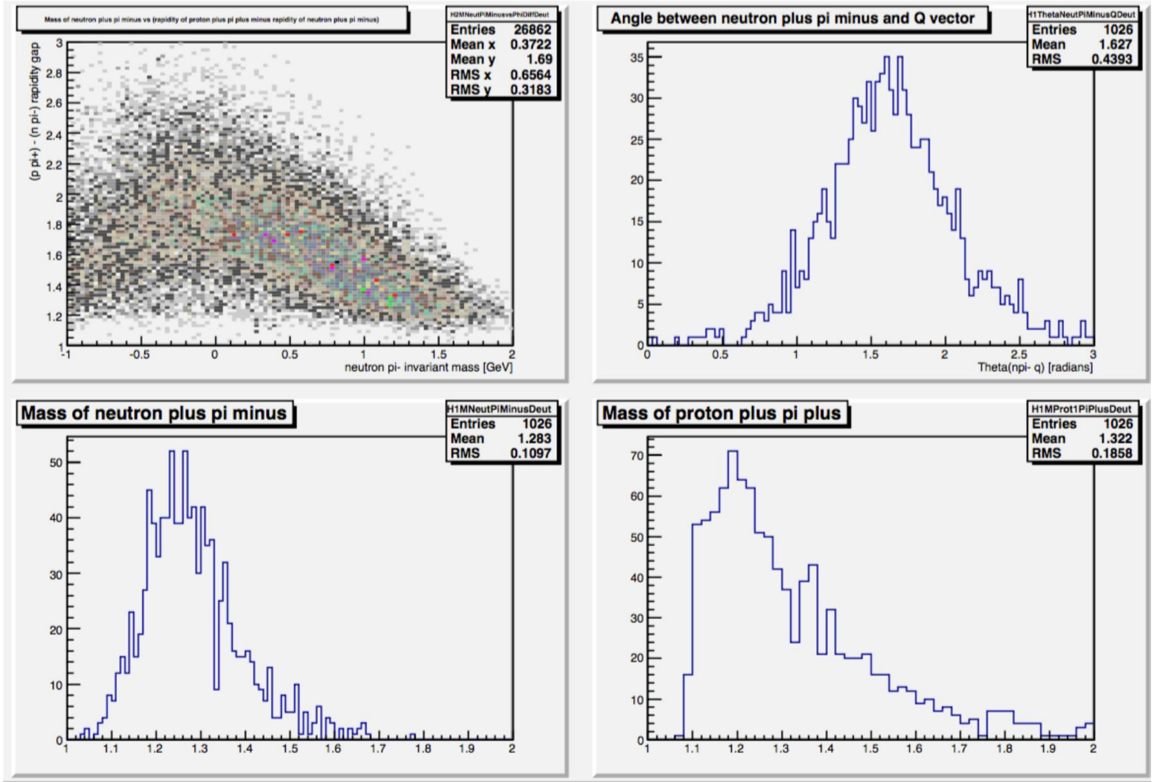

FIG. 5: Preliminary: (upper left) the difference in rapidities between the $(p\pi^+)$ and the $(n\pi^-)$ (the rapidity gap) plotted versus the $n\pi^-$ invariant mass; (upper right) the angle between the momentum of the $(n\pi^-)$ and the momentum transfer, cut on rapidity gap; (lower left) the invariant mass of the $(n\pi^-)$ cut on rapidity gap; and (lower right) the invariant mass of the $(p\pi^+)$ cut on rapidity gap.

F. R-Process Nuclei

R-process nucleosynthesis is one of two processes responsible for the formation of neutron-rich nuclei heavier than iron. The importance of understanding r-process nucleosynthesis has motivated the construction of FRIB, the Facility for Radioactive Ion Beams. Modeling the r-process requires accurate values for parameters such as the nuclear mass, half life, and decay constants, especially for isotopes near the closure of the neutron shells. By measuring $(e, e'p)$, $(e, e'pp)$, $(e, e'ppp)\ldots$ from nuclei such as lead, we can determine the ground state masses of $N = 126$ isotones.

EG2 data for 5-GeV electron scattering on Pb was skimmed for events with one or more knocked-out protons. The missing mass spectrum for Pb$(e, e'p)^{207}$Tl was fit with a gaussian peak and a heaviside background to determine the experimental resolution. The mass was measured to be $M_{\mathrm{Tl}} = 192.799 \pm 0.0003$ GeV/c^2, in excellent agreement with the accepted value of 192.799756 GeV/c^2. The missing mass spectra for $2p, 3p, 4p$ and $5p$ knockout from Pb were fit, with the peak widths constrained by the ^{207}Tl result. The number of events and the binding energies are shown in Fig. 6. The systematic uncertainty from the fitting is related to the difference between the points fit using the two different peak widths. These are the first measurements of the binding energies of elements with mass numbers 205, 204 and 203. Note that there are only 6 counts in the ^{203}Ir peak so that the uncertainty is large.

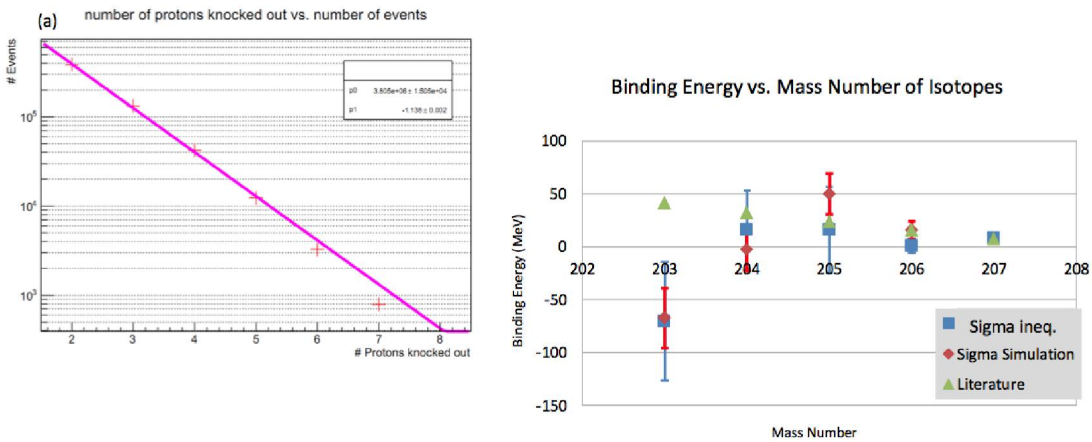

FIG. 6: PRELIMINARY (a) An exponential fit to the number of events versus number of protons knocked out. (b) Plot of the binding energy for different isotopes. Blue squares show the data with peak width fixed at $\sqrt{N_p} \times \sigma_{\mathrm{Tl}}$ (where N_p is the number of knocked-out protons and σ_{Tl} is the width of the ^{207}Tl missing mass peak); red diamonds show the data with the peak width fixed by the results of a GSIM simulation (at values close to σ_{Tl}); and green triangles show the values from the literature.

This innovative technique shows significant promise for providing more information about isotones important for r-process modelling. The technique will be further developed using data from other nuclear targets, such as calcium. The real photon data will also be analysed. Data with light nuclear targets will allow measurements up to and beyond the neutron dripline. With the upgraded CLAS12 facility there will be possibilities to explore even higher multiplicity proton knockout, which should allow nuclei directly in the r-process path to be generated.

IV. THEORY SUPPORT

Within the data mining initiative, there were several theoretical activities. Some of them were directed towards the support of ongoing data analysis and the others represent the initiation of new theoretical research with the goal of establishing a new methodology in probing short range properties of nuclei. These activities were performed by M. Sargsian and M. Strikman.

The theory effort focused on several issues related to physics of Short Range Nucleon Correlations, Non-nucleonic Degrees of Freedom in the Deuteron as well as possible extraction of the ϕ-meson nucleon interaction cross section at the threshold.

A. SRC Studies:

The theoretical studies performed within the framework of the project were focusing on developing predictions of the SRC model for asymmetric nuclear matter. It was argued that the probability for a proton in heavy nuclei to belong to a NN-SRC pair grows with A for $A \sim 200$ even though the average SRC probability, a_2, practically saturates. An effective method for checking these predictions using data mining was suggested and carried out.

B. Tagged structure functions

To understand the origin of the EMC effect it is very important to perform measurements of the tagged structure functions in the electron - deuteron scattering. In determining an optimal kinematic cuts it is critical to know what is the x-dependence of the bound nucleon parton distribution function modification. Such an analysis was performed in Ref. [10] suggesting that to reach a large tagging effect one needs to reach $x \sim 0.6$.

C. Non-Nucleonic Components in the Deuteron:

Preparations were performed for detailed calculations of the reactions of break up of the deuteron with production of Δ-isobars in the kinematics where Δ's cannot be produced

in scattering off a quasifree nucleon. Such studies are currently possible to perform only within the framework of the data-mining collabration, since no other existing data sets from other experiments allow such investigations.
– Another direction in probing non-nucleonic components in the deutron is studies of the electroproduction and rescattering of the $S_{11}(1535)$ resonance in the deuteron break-up reaction. It is believed that the $S_{11}(1535)$ resonance has an anomalously large size which can be checked through the hadronic rescattering processes. This resarch is part of the experimental thesis project of Eric Pooser (FIU) for whom we provide the theoretical support.
– We started also to explore possibilities of getting information about the spin structure of the deuteron wave function from the data on polarized electron - vector polarized deuteron scattering. This study has an important potential of advancing our understanding of the relativistic structure of the deuteron at small distances.

D. Photoproduction of phi-mesons from the Deuteron:

Together with graduate student Adam Freese we studied near-threshold photoproduction of the ϕ-mesons from the deuteron with the quasielastic break-up of the deuteron. We demonstrated that such processes are very sensitive to the $\phi - N$ scattering cross section at threshold for which there are conflicting results from different previous measurements. Our focus now is to to attempt the first extraction of such cross sections from the current data set of the data-mining collaboration.

V. COLLABORATION ORGANIZATION

As part of this effort, we organized the Data Mining Collaboration and met to discuss the data mining software, analyses of the data, and different theoretical signals to look for in the data. Meetings alternated between Jefferson Lab (as part of CLAS Collaboration meetings) and collaboration institutions.

The collaboration met on 24 August, 2011 at Jefferson Lab to discuss collaboration organization and the tasks for the Data Mining Scientist. A dedicated data-mining workshop was held in conjunction with the CLAS Collaboration meeting on 2425 Feb., 2012. Another dedicated workshop was held before the Gordon Photonuclear Conference on 3 August, 2012 at MIT in Cambridge, MA. A meeting was held as part of the Joint INT/JLab Workshop "Nuclear Structure and Dynamics at Short Distances", 20 Feb, 2013, in Seattle, Washington. In addition to talks presented at CLAS Collaboration meetings, the collaboration met at Tel Aviv University on 2 July 2013 as part of the "QCD in the Nuclear Medium: Workshop in honor of Eli PIasetzky's 60th birthday". It also held two International Workshops on Experimental and Theoretical Topics in CLAS Data Mining, one at MIT on 9 August 2014, and one at Canisius College in Buffalo NY on 27-28 July 2015.

The full list of talks is shown in section VIIA.

VI. BIBLIOGRAPHY

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VII. PUBLICATIONS, TALKS, AND THESES

A. Publications

O. Hen, *et al.* [The CLAS Collaboration], "Measurement of transparency ratios for protons from short-range correlated pairs", Phys. Lett. B **722**, 63–68 (2013).

O. Hen, *et al.*, [The CLAS Collaboration], "Momentum sharing in imbalanced Fermi systems", Science **346**, 614 (2014).

B. Workshops

- Data Mining Workshop, 24–25 February, 2012, Jefferson Lab, Newport News, VA.
    1. Gagik Gavalian, Old Dominion University: "Data Mining Project"
    2. Or Hen, Tel Aviv University: "Probing pp-SRC in 12C, 56Fe, and 208Pb using the A(e,e'p) and A(e,e'pp) reactions"
    3. Or Hen, Tel Aviv University: "Tagged EMC Effect"
    4. Or Hen, Tel Aviv University: "Momentum and Acceptance Corrections for pp-SRC analysis"
    5. Wim Cosyn, Ghent University: "Counting correlated pairs and pair center of mass motion inuence"
    6. Michael Mayer, Old Dominion University: "Analysis of e6 Data"
    7. Misak Sargsian, Florida International University: "(a) Nuclear Momentum Distribution Beyond 300 MeV/c (b) The ABC Effect for Deuteron Quasi Fusion Reaction"
    8. Gagik Gavalian, Old Dominion University: "Analysis Framework Demonstration"
- Data Mining Workshop, 4 August, 2012, MIT, Cambridge, MA
    1. Claudio Ciofi degli Atti: "The relative and CM motions of a correlated pair in nuclei", stressing the decrease of the pair relative momentum distribution with increasing value of the CM momentum, and the possibility to check such a behavior by data mining.
    2. Jan Ryckebusch: "Short-range correlations in exclusive and inclusive electron-scattering measurements"
    3. Or Hen: "Transparency of SRC-nucleons in A(e,e'pN) and A(e,e'p)"
    4. Or Hen: "Neutron detection efficiency in CLAS"
    5. Misak Sargsian "New properties of high momentum component of nuclear wave function and the EMC effect"

6. Mark Strikman: Extraction of the x-dependence of the bound nucleon quark modification and implications for tagging
7. Sebastian Kuhn "New deuteron EMC results"
8. Adam Freese: "Possible two peak structure of deuteron photodisintegration with mesons"
9. Larry Weinstein "The difficulties of selecting double delta events in d(e,e'pp pi-) data"
10. Gagik Gavalian: Data Mining Software tutorial

- Data Mining Talks presented at the Nuclear Physics Working Group, CLAS Collaboration meeting, 12 October 2012, Jefferson Lab, Newport News, VA

  1. Michael Mayer "Update on e6 analysis"
  2. Gagik Gavalian "Data Mining Project Progress"

- Data Mining session at the Nuclear Structure and Dynamics at Short Distances, Joint JLab/INT Workshop, INT, Seattle, Washington

  1. Larry Weinstein "CLAS Data Mining Initiative"
  2. Or Hen "Recent Results from Exclusive Studies of Two-Nucleon SRCs"
  3. Werner Boeglin "Mining for N*"
  4. Maarten Vanhalst "Monte Carlos Simulations for (e,e'pp) Reactions"
  5. Adam Freese "Probing Phi-Mesons in Deuteron Break-Up Reactions"

- Data Mining session at QCD in the Nuclear Medium, Tel Aviv University, Tel Aviv, Israel

  1. Larry Weinstein "Overview and Status of the JLab Data-Mining Initiative"
  2. Stephen Wood "Nuclear Physics at JLab 12 GeV"
  3. Gagik Gavalian "Data Accessibility: Mining Software"
  4. Barak Schmookler "Inclusive and Semi-Inclusive studies of the EMC Effect"
  5. Larry Weinstein "Delta-Delta Correlations in the Deuteron"
  6. Or Hen "(e,e'p) Studies of Mean-Field and Correlated Protons in Asymmetric Nuclei"
  7. Michael Braverman "Neutron Extraction and Study of d(e,e'p) and (e,e'pn) scattering"
  8. Misak Sargsian "Recent Results in Studies of High Momentum Component of Nuclei"
  9. Wim Cosyn "Final-State Interaction in Inclusive DIS and QE Scattering off the Deuteron"

10. Adam Freese “Probing under - and - above threshold Photo-production of Vector Mesons from Nuclei”
11. Mark Strikman “Probing Delta-Delta Correlations”

- International Workshop on Experimental and Theoretical Topics in CLAS Data Mining, MIT, Cambridge, MA 9 August 2014

  1. L. Weinstein “Welcome and Data Mining Status”
  2. M. Wood “Hadronization of the omega meson”
  3. O. Hen “Short Range Correlated Pair motion from A(e,e’pp)”
  4. M. Braverman “Neutrons and A(e,e’n)”
  5. B. Schmookler “Tagged EMC Effect”
  6. M. Sargsian “Three-nucleon Short Range Correlations, symmetry energy, and two-Delta components”
  7. M. Strikman “Data mining - directions for the further studies - theorists view”
  8. J. Ryckebusch “Single-momentum distributions and Short Range Correlations (arXiv:1405.3814)”
  9. W. Brooks “Distinguishing partonic FSI from hadronic FSI using transverse momentum broadening”
  10. M. Sargsian “The nuclear symmetry energy”
  11. O. Palamara “Correlations in neutrino-induced events”
  12. T. Katori “Nucleon correlation in neutrino oscillation experiments”

- International Workshop on Experimental and Theoretical Topics in CLAS Data Mining, Canisius College, Buffalo, NY, 27–28 July, 2015

  1. G. Gavalian “Data Mining Software Status”
  2. L El Fassi “Data Conversion Progress”
  3. Kendall Mahn “Neutrino Physics and Data Mining”
  4. L. Weinstein “Data Mining for Neutrino Physics”
  5. M. Wood “Omega analysis status”
  6. W. Brooks “Modelling hadronization measurements”
  7. B. Schmookler “Tagged EMC Effect Analysis”
  8. M. Khachatryan “3H(e,e’p) and (e,e’n)”
  9. K. Adhikari “Hadronization of Lambda0 channel: analysis progress”
  10. M. Duer “Study of the A(e,e’n) reaction”
  11. E. Cohen “The center of mass motion of SRC pairs”
  12. E. Cohen “The search for 3-proton SRC”
  13. S. Kuhn “The Future of the Data Mining Collaboration”

C. Talks, Colloquia and Seminars

1. Or Hen "Mining for Proton-Proton Correlations", invited talk presented at the International Workshop on Short Range Correlations in Nuclei and Hard QCD Phenomena, European Center for Theoretical Physics, Trento, Italy, 17 November 2011.

2. Or Hen "Short-range structure of nuclei", invited talk presented at the Jefferson Lab Users Group Annual Meeting, Jefferson Lab, Newport News, VA, 4-6 June 2012.

3. Michael Mayer "Beam-Target Double Spin Asymmetry in $\vec{D}(\vec{e}, e'p)n$", invited talk presented at the APS April 2012 Meeting, Atlanta, GA, April 2012.

4. Eli Piasetzky "Disentangling the EMC Effects", invited plenary talk presented at CIPANP 2012, the Eleventh Conference on the Intersections of Particle and Nuclear Physics, St. Petersburg, FL, May 2012.

5. Eli Piasetzky, "High-Momentum Components of the Nuclear Wave function: Short Range correlation, the tensor NN interaction, and the EMC effect", International workshop in the Extreme Matter Physics of Nuclei, EMMI/GSI Darmstadt, Germany April 2012.

6. Lawrence Weinstein "Short Distance Structure of Nuclei: Mining the Wealth of Existing Jefferson Lab Data", invited talk presented at the International Workshop on Short Range Correlations in Nuclei and Hard QCD Phenomena, European Center for Theoretical Physics, Trento, Italy, 17 November 2011.

7. A. Freese, "Near Threshold Photodproduction of J/Psi mesons from the deuteron", poster presentation at the Gordon Research Conferences on Photonuclear reactions, Holderness, NH USA, 5-10, August 2012.

8. O. Hen, "Measurement of Transparency Ratios for Protons from Short-Range Correlated Pairs", Israel Joint Nuclear Seminar, Weizmann Institute, Rehovot, Israel, Nov 26, 2012.

9. O. Hen, "Short Range Structure of Nuclei", Jefferson Lab User Group Meeting, Newport News VA, June 6, 2012.

10. M. Strikman, "Hard Nuclear Reactions, SRCs and QCD," Gordon research conference, Photonuclear Reactions, August 9, 2012.

11. M. Strikman, "Nucleon close encounters," Miniworkshop on short range correlations, Beijing University, China, October 2012.

12. M. Strikman, "Emergence of light-cone dynamics in hard nuclear processes", Miniworkshop on short range correlations, Beijing University, China, October 2012.

13. M. Strikman, “Short-range nucleon correlations in nuclei: direct observation and applications”, Miniworkshop on short range correlations, Lanzhou, China, October 2012.

14. M. Strikman, “Light Cone Nuclear Physics and SRC/EMC Effects”, Joint INT/JLab Workshop on Nuclear Structure and Dynamics at Short Distances, February 19, 2013.

15. S. Manly and H. Lee, “eA pion production aimed at neutrinos”, NUFACT 2013 (International Workshop on neutrino factories, super beams and beta beams), Beijing, China), Aug. 2013

16. S. Manly and H. Lee, “eA pion production aimed at neutrinos”, Inst. For Nuclear Physics workshop, Dec. 2013, Seattle, WA.

17. S. Manly and H. Lee, “eA pion production aimed at neutrinos,” NUINT 2014 (9th International workshop on neutrino-nucleus interactions in the few-GeV region), London, England, May 2014

18. S. Manly and H. Lee, “eA pion production aimed at neutrinos”, CETUP* 2014 (Workshop at Center for Theoretical Underground Physics and Related Areas), Deadwood, SD, July 2014

19. L. Weinstein “Data Mining for Short Range Correlations”, invited talk presented at the Hall C Summer Workshop, Jefferson Lab, Newport News, VA, August 16, 2013.

20. L. Zana and D. Watts “Some ideas and possibili.es for nuclear target measurements with new genera.on electron beams”, invited talk presented at “New Directions in Nuclear Deep Inelastic Scattering”, ECT*, Trenta, Italy, 8–12 June 2015.