GlueX LOI

Probing short-range nuclear structure and dynamics with real photons and nuclear targets at GlueX

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Abstract. We propose to measure the $A(\gamma,X)$ and $A(\gamma,XN_{recoil})$ reactions for A = ^{2}H, ^{4}He, ^{12}C, ^{28}Si, ^{40}Ca, ^{48}Ca, ^{54}Fe, ^{111}Ag, and ^{208}Pb (where X represents a wide range of baryon-meson final states) using the maximum possible rate of coherent bremsstrahlung photons at E_e = 12 GeV (i.e. 8-9 GeV real photons) and, if possible, also at E_e = 6 GeV during Hall-A parity-violation half energy per-pass running.
The data will be used to address the following issues:

- Possible modification of nucleon structure (as measured by the decomposition to various Fock states) in nuclei.
- Contributions of protons and neutrons to the high momentum tails of asymmetric nuclei.
- Transition from mean field to SRC ('Migdal jump').
- The reaction of Quasi-Elastic scattering off a single nucleon in SRC pair.
- Discovering the transition from hadronic to a single parton photon dominance.
- CT for different particles and reactions.

We estimate this measurement will require a total 74 days at 12 GeV: 30 days with a deuteron target, 14 days with ^{4}He, and 30 days with the other nuclear targets. Pending scheduling constraints, we could benefit from an additional 30 days at 6 GeV divided in a similar way between the different targets.

1. Scientific Motivation

Understanding the interplay between the partonic and nucleonic degrees of freedom in the QCD description of nuclei has been a goal of modern nuclear physics research and of the Jefferson Lab physics program in particular [1]. An area of study that clearly combines the two is the study of Short-Range Correlations (SRC) in nuclei: pairs of high-momentum nucleons in nuclei whose wave functions considerably overlap [2-10].

SRC pairs have important consequences for nuclear structure, hadronic physics, and high-energy physics. Nucleons at short-distance experience a very strong short-range interaction, generating a high-momentum tail to the nuclear wave function. The creation of such a high-momentum tail due to a strong short-range interaction is a universal feature of two-component Fermi systems with a short-range interaction and was shown experimentally to also exist in systems of ultra-cold atomic gases and have wide-ranging implications for their macroscopic properties [11].

The short-range structure of nuclei is therefore a vibrant and important field of research with wide-ranging implications for fundamental nuclear physics and various subfields in astrophysics, atomic, and particle physics. Recent works have shown that short-range correlations inside the atomic nucleus have significant implications on the nuclear symmetry energy and neutron stars structure, the quark distributions in nuclei (the "EMC effect") and the free (un-bound) neutron structure, energy sharing and correlations in ultra-cold two-component Fermi-gases in atomic physics, neutrino-nucleus interactions, and the analysis of neutron oscillation experiments and more.

While the 6 GeV physics program at Jefferson-Lab revolutionized many aspects of our understanding of the properties and importance of SRC pairs in nuclei, there are still many aspects of correlations we do not understand, ranging from 'nuclear' aspects such as the transition from tensor to central correlations and the dependence of correlations on nuclear asymmetric, to more 'partonic' aspects such as the possible connection between short-range correlations and the EMC effect [12-15].

This LOI presents a research program for the GlueX detector that will utilize the unique properties of photonuclear reactions off nuclear targets to study properties of SRC pairs in nuclei, nuclear transparency mechanisms, search for color transparency, and offer new observables to search for modification of the structure of bound nucleons - shedding new light on the quark-gluon structure of bound nucleons.

1.2. Nucleon structure

The interplay between partonic and nucleonic degrees of freedom in the QCD description of nuclei can manifest itself in various ways. One of the most prominent ones is the possible modification of the partonic structure of nucleons bound in nuclei, due to the strong nuclear interaction between them. Since the strong nuclear interaction is responsible for the stability of atomic nuclei, this modification is fundamental to our understanding of nuclear dynamics. Experimentally, considerable evidence for such modification were first reported over 30 years ago by the EMC collaboration at CERN who observed a reduction in the Deep Inelastic Scattering (DIS) cross section per nucleon in nuclei relative to the deuteron (known as the

EMC effect [12-13]). While numerous theories tried to explain the origin of the EMC effect, and its specific dependence on the nuclear mass number, it still lacks an accepted theoretical explanation.

In recent years, guided by results of Drell-Yan measurements and high precision measurements of the EMC effect in light and heavy nuclei at SLAC and JLab, it has become accepted that any explanation of the EMC effect must include modification of the bound nucleon structure function in the nuclear medium. Understanding the physical mechanism driving this modification is the focus of a large ongoing experimental and theoretical effort.

There are two main approaches to explain the physical mechanism driving the EMC effect: On the one hand, it was proposed that the strong mean field of the nucleus modifies all the bound nucleons [16]. On the other hand, the strength of the EMC effect was found to be linearly correlated with the relative amount of Two-Nucleon SRC pairs (2N-SRC) in nuclei. This observed correlation indicates that the EMC effect, like 2N-SRC pairs, is related predominantly to the high-momentum (large virtuality / large offshell) nucleons in the nucleus [14-15].

To test these models and distinguish between them, *new observables are required*. In this LOI we propose to measure the variation in the Branching Ratios (BRs) for hard photonuclear reactions off free (/quasifree) vs. deeply bound nucleons in the deuteron and heavy nuclei. Changes in the measured BRs, which may depend on the momentum transfer, scattering angle and nuclear transparency, will shed new light on the mechanisms of quark-gluon nucleon structure modification in nuclei. The detailed description of this novel observable follows.

The proton (or neutron) is a complex system that can be described in QCD at any given moment as a superposition of different Fock states:

Eq. 1:

$$\begin{aligned} &\left|proton\right\rangle = \alpha_{PLC}\left|PLC\right\rangle + \alpha_{3qg}\left|3q+g\right\rangle + \alpha_{3qq\bar{q}}\left|3q+q\bar{q}\right\rangle + \alpha_{3q\pi}\left|3q+\pi\right\rangle + \ldots \\ &|\alpha_{PLC}|^2 + |\alpha_{3qg}|^2 \ldots = 1 \end{aligned},$$

where the different brackets represent states of the proton (or neutron) with the corresponding α representing the amplitude of each state. By definition all weights must sum to 1. The minimal state of the nucleon includes only the 3 valence quarks and is assumed to be small in size and with a reduced strong interaction. Such states are referred to as Point Like Configuration (PLC). The other states include more complex configuration involving additional gluons, quark-antiquark pairs, pions etc. *These states are all components of the wave function of the nucleon*.

The modified structure of a proton (or neutron) bound in a nucleus can then be represented by a different, decomposition into the same Fock states:

Eq. 2:

$$\begin{aligned} &\left|proton^*\right\rangle = \alpha^*_{PLC}\left|PLC\right\rangle + \alpha^*_{3qg}\left|3q+g\right\rangle + \alpha^*_{3qq\bar{q}}\left|3q+q\bar{q}\right\rangle + \alpha^*_{3q\pi}\left|3q+\pi\right\rangle + \ldots \\ &|\alpha^*_{PLC}|^2 + |\alpha^*_{3qg}|^2 + \ldots = 1 \end{aligned}$$

where the difference between a free and bound proton is depicted by the difference between the α and α* coefficients in Eqs. 1 and 2. An example of such an effect can be found in the

‘Point Line Configurations Suppression’ model of Frankfurt and Strikman [17] or the ‘Blob Line Configurations Enhancement’ model of Miller and Smith [18] that propose a possible explanation to the EMC effect in which the PLC part of the bound nucleon is different than in a free one.

We stress that the Fock space description of bound nucleons is somewhat more complex as nucleons bound in nuclei span various states: e.g. mean-field vs. SRC nucleons, high vs. low local density etc., allowing the α* coefficients to possibly depend on the detailed nuclear state of the bound nucleon. For example, in the PLC suppression model [17], $|\alpha_{PLC}^{*}/\ \alpha_{PLC}|^2$ -1 is proportional to the nucleon off-shellness (approximately to the square of the nucleon momentum) with much smaller modification for configurations close to the average ones. Hence one expects maximal bound nucleon modification in the processes dominated by scattering from small size configurations.

We expect that different Fock states will absorb high-energy photons differently and lead to different branching ratios (BR) for various final states (e.g., $\gamma p \to \pi^- \Delta^{++}$ or $\gamma p \to \rho^0 p$). We propose to use the unique capability of GlueX to measure simultaneously the BRs of many decay channels of an excited nucleon following the absorption of a real photon at high momentum transfer (large *t*). By measuring these BR for nucleons in a range of nuclei from deuterium through lead we will be able to see differences in the Fock state decomposition, and hence the structure, of bound and free nucleons.

For a free proton GlueX will measure the branching ratio (BR) for many reactions, including the following:

Eq. 3:

$$\begin{aligned} \gamma p &\to \pi^- \Delta^{++} \\ &\to \rho^0 p \\ &\to K^+ \Lambda \\ &\to K^+ \Sigma^0 \\ &\ldots \end{aligned}$$

By measuring these reactions, and the neutron equivalent, on hydrogen, deuteron and nuclear targets, we can extract the BRs for scattering off free (/quasi-free) vs. deeply bound nucleons. As each reaction is sensitive to a different combination of Fock states, modifying their contribution to the bound proton will modify their BRs.

Current theoretical models do not allow us either to predict the exact change in BRs as a function of the bound nucleon structure, or to translate the observable BRs to the modified α* coefficients**. However, this is a novel observable that allows us to observe or exclude deviations, and to study their dependence on the nucleon momentum and ‘hardness’ of the reaction. Any such observation will therefore serve as clear and direct evidence for changes in bound nucleon structure.**

On average, differences between a bound and a free nucleon are expected to be small. However, we propose to select specific kinematics, focusing on deeply bound nucleons, that could enhance the effect: e.g., selecting hard process with large *s*, *u*, and *t* is expected to emphasize the contribution of the PLC component. Alternatively, detecting the decay products along with a high-momentum recoil nucleon (which favors scattering from a nucleon from an SRC pair) should also significantly amplify the medium effect to the level observed for the EMC effect at $x_B \sim 0.5 - 0.6$ that is modification on the scale of 20%. The high-momentum recoil nucleons can best be studied with a deuteron target.

In the case of nuclear targets, the measured BRs are not at the photon absorption point but rather following hadron attenuation in the nucleus, which may be different for each channel. To extract the BR at the hard vertex of the quasi free scattering we need to correct for hadron attenuation in the nucleus. We propose to do that by measuring the process on different nuclei, from deuterium to lead, that span the periodic table. This will yield by itself, as a byproduct, an interesting study of photon and Color Transparency (CT). as well as measure pattern of interaction with media of different mesons. See separate discussion on CT below.

1.3. Nuclear structure (SRC)

We propose here to utilize the high intensity photon flux and the large acceptance of the GlueX spectrometer to perform a new generation of exclusive and semi exclusive SRC studies using the $A(\gamma, X)$ and $A(\gamma, XN_{recoil})$ reactions. Here *X* stands for the leading meson and baryon in the different channels listed in Eq. 3 for the proton and the equivalent for the neutron. N_{recoil} stands for a correlated recoil nucleon emitted in the case of photon-absorption on a nucleon that is part of a 2N-SRC pair.

While previous SRC studies using electron beams (i.e. virtual photon exchange) were mainly probing a proton in the SRC pair [3-11], the use of a real photon beam opens a new window to SRC studies by allowing us to probe, for the first time, the neutron in the pairs. The main goals of this measurement are to study the role of high momentum nucleons in nuclei and the role played by neutrons versus protons. An important advantage of the discussed reactions is the possibility to select kinematics where the products of interaction with SRC have large relative momenta leading to a great reduction and simplification of the FSIs.

We list below some of the research subjects that can be addressed by SRC studies with GlueX:

- **The isospin structure of the high momentum tail in asymmetric nuclei**
  A unique signature of the dominance of the tensor part of the nuclear interaction at short distance is the large ratio of np- to pp-SRC pairs [19], observed directly in measurements of symmetric nuclei (^{4}He and ^{12}C) [6,10] and indirectly in measurements of asymmetric nuclei (^{27}Al, ^{56}Fe, and ^{208}Pb) [11]. We propose to perform a direct detailed study of SRC pairs in asymmetric nuclei.

- **Mapping the transition from mean field to SRC**
  The first measurements of SRC pairs in proton scattering data from Brookhaven [20] showed an amazing clear transition between the mean field and the SRC domains, but did not have enough statistics to precisely map that transition. We will measure the proportion of photo-proton events (e.g., $\gamma p \to \pi^- \Delta^{++}$) with and without accompanying recoil neutrons as a function of the missing momentum. The GlueX recoil neutron

detection efficiency for neutrons with momentum above 250 MeV/c can yield higher statistics data that will tell us much more about this intriguing transition.

- **Probing the repulsive core of the NN interaction**
  Experimentally, we know very little about the repulsive core of the NN interaction. Different extractions of the NN potential vary significantly in their description of this part of the interaction and current experimental data has very limited ability to constrain theory. By measuring the ratio of np/pp SRC pairs in nuclei at very high missing momentum we can probe the transition from the tensor dominant region of the NN interaction to the repulsive core and, for the first time, probe its properties for nn, pp, and np pairs.
- **Reaction Mechanism**
  The high intensity real photon beam and the ability to detect many final state reactions allow us to test the assumed reaction mechanism of quasi-free scattering off a single nucleon in a pair and a recoil partner. Obtaining consistent results using proton, electron, and photon induced reactions at different kinematics is a key test to support our understanding of the underlying reaction mechanism.

1.4. Nuclear Transparency studies

As stated above, we need to measure the ratio of free to bound nucleon for as many reactions as possible as a function of *A* (the nuclear mass number) over a broad range of nuclei to extrapolate reliably to the hard vertex of a 'bound nucleon' with reduced corrections for nuclear filtering.

However, the search for nuclear transparency of the different particles produced in the hard photon absorption vertex has a scientific merit by itself. Under the proposed kinematical condition theoretical predication show nuclear attenuation with major deviation from the standard Glauber calculation. These deviations are associated with the nature of the rescattering mechanism and the type of particles involve.

The ability of the GleuX spectrometer to detect hard exclusive two body processes of the kind:

$$\gamma + A \to h_1 + h_2 + (A-1)^*,$$

(where h_1 and h_2 are the two outgoing hadrons) allows addressing a number of important aspects of nuclear transparency:

(a) Photon transparency: At certain kinematical conditions (e.g. low momentum transfers, *t*) the photon interacts as a vector meson and at higher $-t$ as single parton. Can we map the transition between these?

(b) how different are the interactions of different outgoing mesons and baryons?

(c) Color Transparency (CT) is when hadrons are produced in squeezed configurations and weakly interact with other nucleons on the way out of the nucleus. Can we observe CT for hadrons? If so, what are the required kinematical conditions for observing this effect?

In soft intermediate-energy photohadron production processes the photon is usually treated as superposition of hadronic states of moderate masses. In hard processes (high energy, large momentum transfer) these states are suppressed by a factor s^{-1} as compared to the single parton - a photon. Scattering off nuclei provides a sensitive probe of the transition between these soft and hard behaviors. The single photon penetrates the nucleus up to the hard interaction with less interaction. The effective coherence length in this case is essentially infinite and the photon can interact with all nucleons near the back surface of the nucleus producing a pair of hadrons which can escape without absorption, leading to a $\sigma \propto A^{2/3}$dependence. In contrast, in the hadronic state only the rim of the nucleus contributes i.e. the transparency is lower, the A dependence is different ($\sigma \propto A^{1/3}$), and the Glauber approximation can describe the process. See in Figure 1 the calculation of [21] to demonstrate the expected large size of the effect.

Assuming the transition to be at about $t = -2\ \text{GeV}^2$ [21] it would be feasible to study this transition for different channels. It may depend on quark composition (compare π and η) and the spin of the final state (compare π and ρ).

The available data show substantial differences between the nuclear attenuation of protons and mesons (π, ρ) produced in hard processes. The Hall D beam line and the GlueX detector allow us to study large numbers of hard exclusive reactions with a large variety of different emerging particle (η, φ, K+, K+*, Λ…). Comparing different inelastic reactions in different nuclei at kinematical conditions that are optimal for observing CT and others kinematics will allow to constrain our understanding of the underline dynamics of these rescattering processes.

These measurements also allow us to determine an effective cross section for the scattering of the outgoing particles with a nucleon $(\sigma_{\eta N}, \sigma_{\Phi N} ...)$. The additive quark model describes well the ratio between the πN, KN, and NN cross sections but not necessary the other meson-nucleon cross sections. Some of these can be extracted from the GlueX photo production data. This data will lead to a better understanding of the process which cannot be well described by perturbative simple quark counting. The sensitivity to the effective rescattering cross section is demonstrated in Figure 2 where the transparency ratio to a standard transparency (like for the $A(\gamma, \pi^- p)$) is shown as a function of the effective cross section.

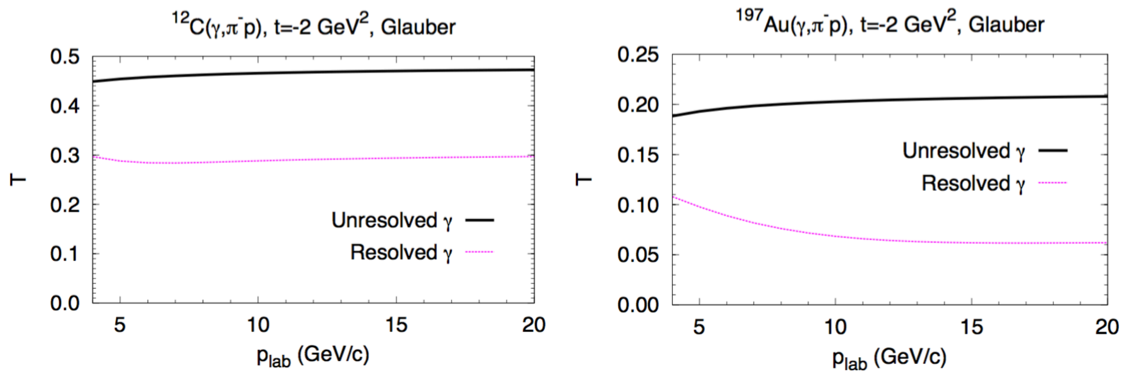

Figure 1: Transparency for the $A(\gamma, \pi^- p)$ reaction calculated with a Glauber model with and without photon attenuation. See [21] for details.

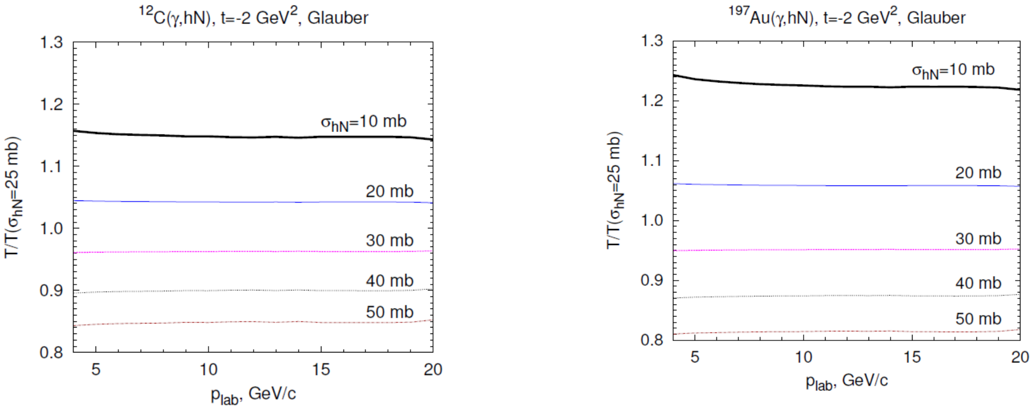

Figure 2: The ratio of transparency for the $A(\gamma,h\ N)$ reaction to the transparency for $A(\gamma,\pi^- p)$ as a function of the effective rescattering cross section, σ_{hN}. The inelastic $\sigma_{\pi^- N}$ was assumed to be 20 mb.

High energy and large angle scattering are natural process to look for CT effects. The hard process emphasizes the contribution of the minimal Fock state with a reduced interaction. The photon allows the vertexes to be distributed all over the nuclear volume and the transparency limit to detected events only if the final state particles succeed to emerge from the nucleus. In the possible kinematics allowed and with the expected statistics of GlueX, Ref [21] predicts a large effect due to CT, i.e., a measureable difference from Glauber calculations.

For example, Figs 3 and 4 show calculations by Larionov and Strikman [21] for the $A(\gamma,\pi^- p)$reaction as a function of the photon energy for fixed 90 degree cm angle scattering and as a function of *t* for fixed incident photon energy.

To summarize, the study of the nuclear transparency of the different particles produced in the hard photon absorption vertex has a scientific merit by itself. Under the proposed kinematical conditions, a major deviation from the standard Glauber calculation and perturbative quark additive predictions are expected. These deviations are associated with the nature of the rescattering mechanism and the type of the rescattered particles. The simultaneous measurement of ~~a~~ few reaction channels and the ability to create ratios and supper ratios of transparencies will allow us to study these processes with small systematic and statistical uncertainties and to strongly constrain the theoretical interpretation. These measurements will complement the approved 12 GeV experiment to study CT in pion and ρ- electroproduction as well as in quasielastic proton knockout.

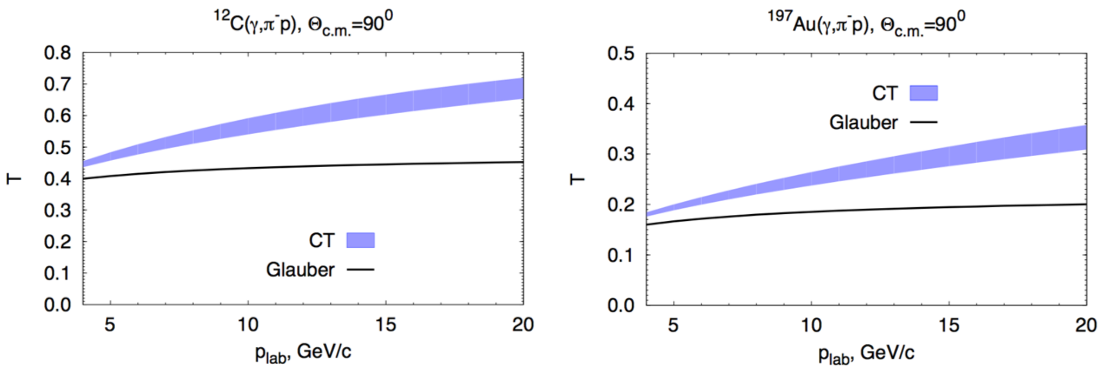

Figure 3: The of transparency for the $A(\gamma,\pi^- p)$ reaction as a function of the photon energy for 90 degree cm scattering angle.

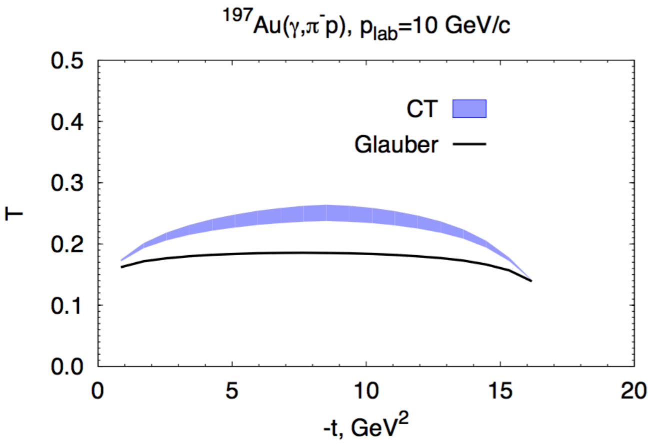

Figure 4: The of transparency for the $^{197}Au(\gamma,\pi^- p)$ reaction as a function of the momentum transfer ,-t. for 10 Gev photon energy.

2. The proposed measurement:

2.2. Kinematics

The kinematical distributions and expected rates were calculated for the various reactions based on measured photonuclear cross-sections and a dedicated Monte-Carlo event generator. In the following we present the calculation method, and show the resulting kinematical distributions for one reaction. Following that we present rates for all other reactions and point to significant changes to the kinematical distributions when needed.

The steps of the calculation are as follows:

1. Choose a photon randomly from the GlueX photon energy distribution and an initial nucleon randomly from a correlated Fermi-Gas model.
2. Boost to the nucleon rest frame and calculate the cross-section for the photon energy in this frame.
3. Boost to the c.m. frame and calculate the scattering for angles of $50^{\circ} \leq \theta_{cm} \leq 130^{\circ}$ Enforce a 'hard reaction' by only keeping events with $|t|$, $|u| > 3$ GeV^2.
4. Weight the event using the cross-section obtained in step 2.

The cross-section for a stationary nucleon is extracted by fitting data for 90° scattering in the c.m. with $s > 6.25$ GeV^2 assuming factorization of the s and c.m. angle dependence, i.e. $\left.\frac{d\sigma}{dt}\right|_{\theta_{c.m.}} = \left(C \times s^{-7}\right) \times f(\theta_{c.m.})$, where C is a free fit parameter and f was extracted from SLAC data assuming $f(90^{o}) = 1$ [22], see Fig. 5.

Figs. 6-8 show kinematical distributions for $\gamma n \rightarrow \pi^{-} p$ at $\theta_{cm} = 90^{\circ} \pm 10^{\circ}$ where the reaction is done off a standing nucleon, a mean-field nucleon, and a nucleon from an SRC pair respectively. GlueX was designed to measure such reactions off standing nucleons. As can be seen, the kinematical distributions for the case of scattering off nucleons bound in nuclei is similar and therefore we expect GlueX to offer high acceptance for these reactions. Different final states are expected to have similar kinematical distributions.

Fig. 9-11 show the same as Fig. 6-8 only with no restriction on the c.m. angle. Fig. 12 shows the angular distribution of the SRC recoil partner nucleon.

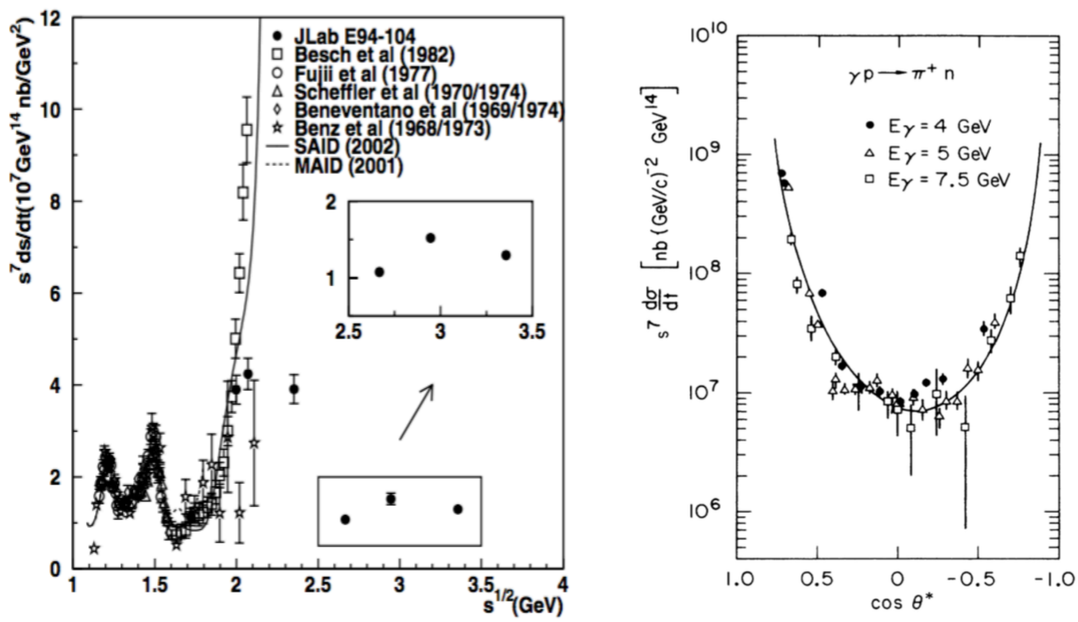

FIG. 6. $s^7 d\sigma/dt$ versus $\cos\theta^*$ for the reaction $\gamma p \to \pi^+ n$. The solid line shows the empirical function $(1-z)^{-5}(1+z)^{-4}$ where ($z = \cos\theta^*$), which is an empirical fit to the angular distribution.

Figure 5: The s dependence of the photonuclear cross-section at 90° in the c.m. (left) and its dependence on the c.m. angle (right). We extract the cross-section by fitting the s dependence at high-s, after the low-s oscillations appear to the over. Figures were adapted from [22].

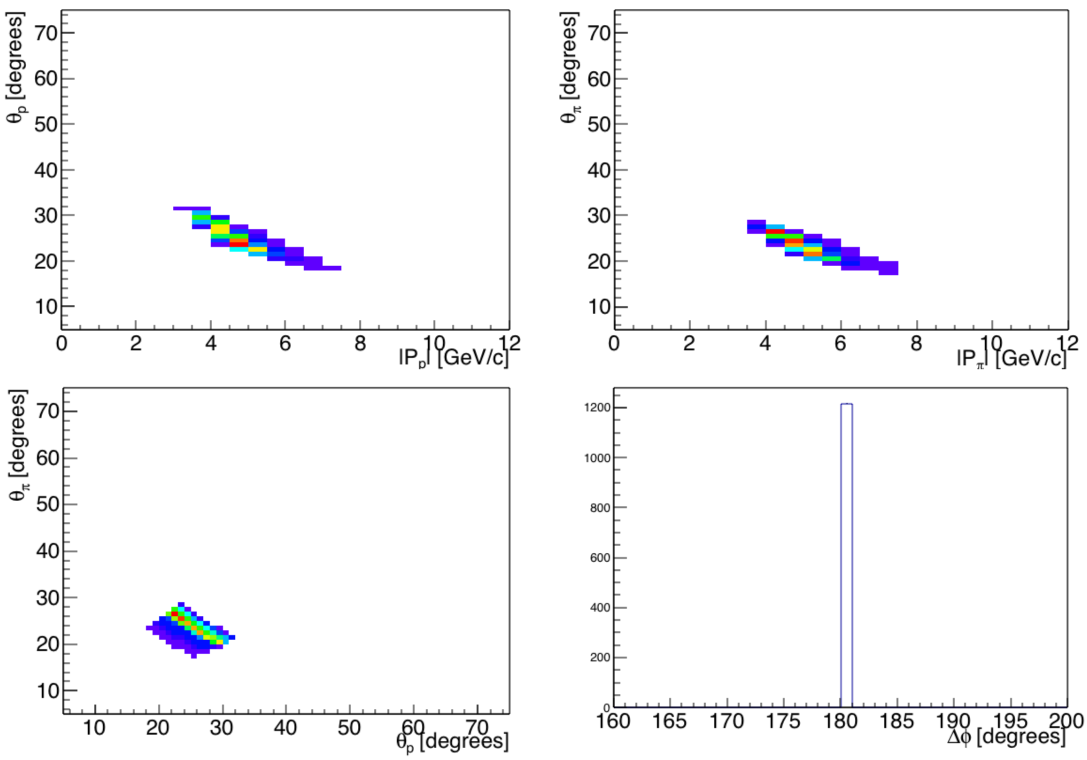

Figure 6: Kinematical distributions for the final state particles in the $\gamma n \rightarrow \pi^- p$ reaction for scattering off standing nucleon at 90° in the c.m.

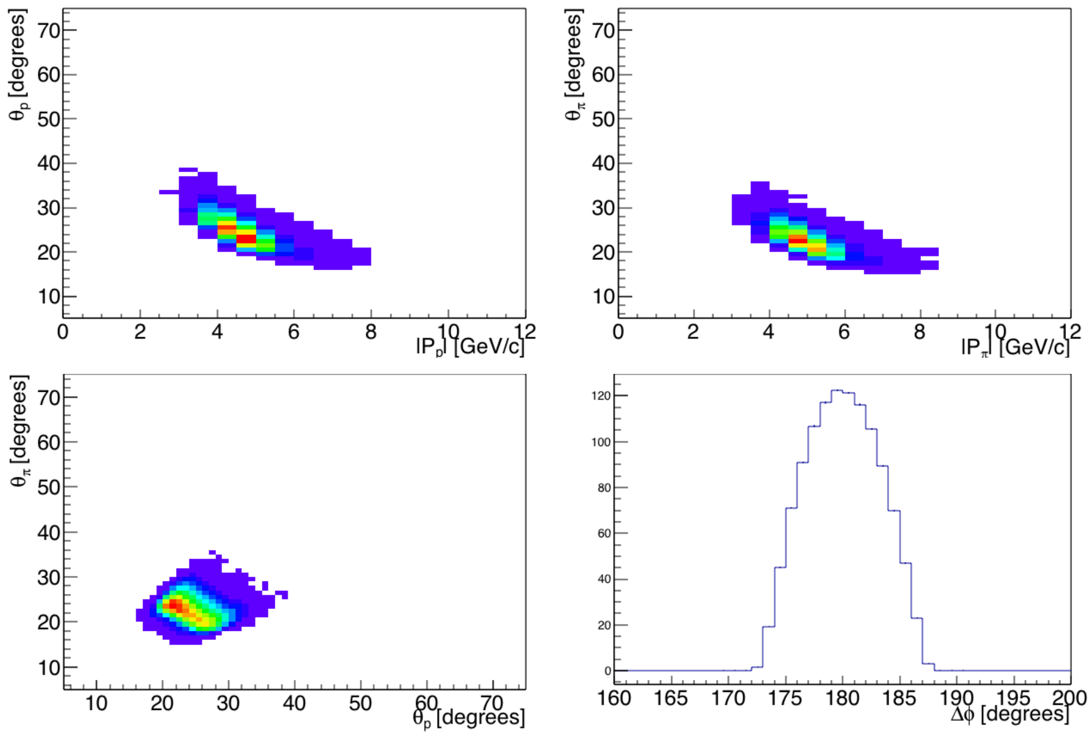

Figure 7: Same as Fig. 6 for scattering off mean-field nucleons in the nucleus (i.e. nucleons with $k < k_F$).

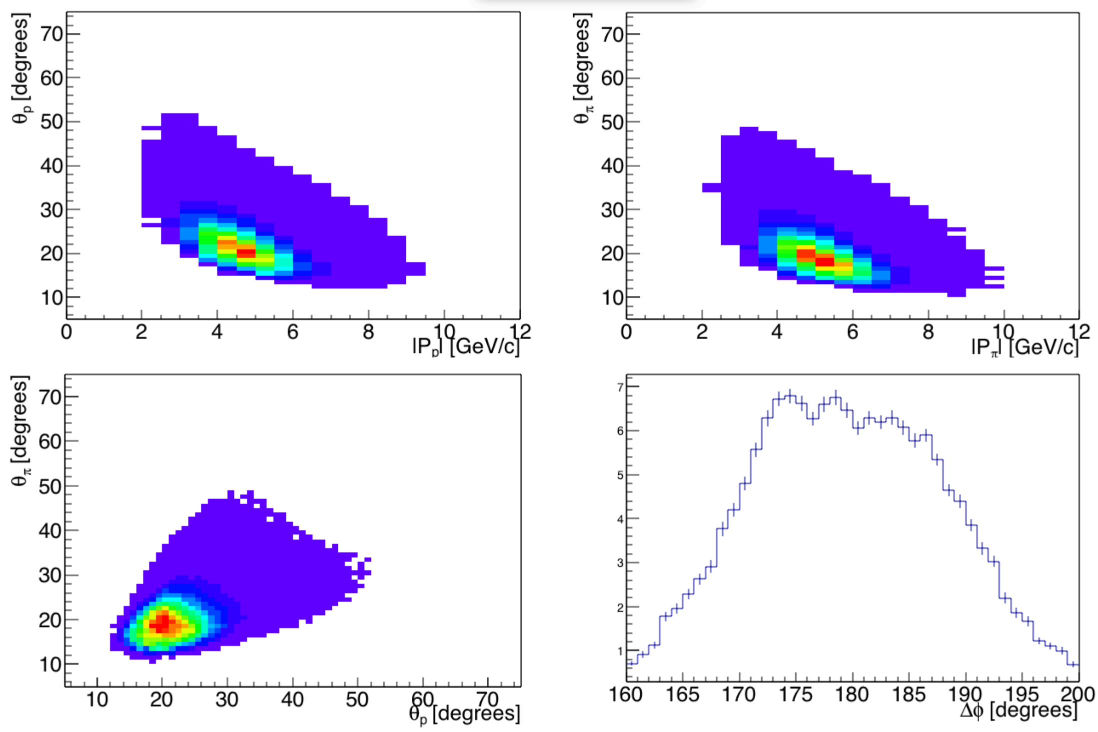

Figure 8: Same as Fig. 6 for scattering off SRC nucleons in the nucleus (i.e. nucleons with $k > k_F$)

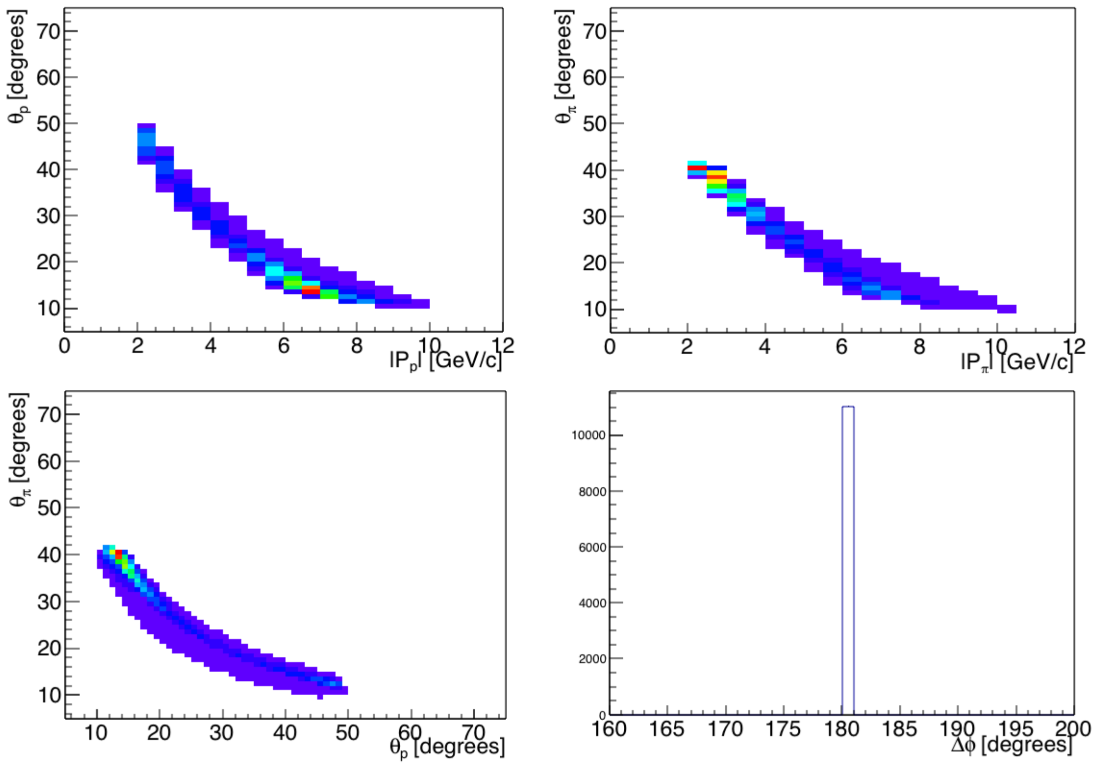

Figure 9: Same as Fig. 6 for all c.m. scattering angles.

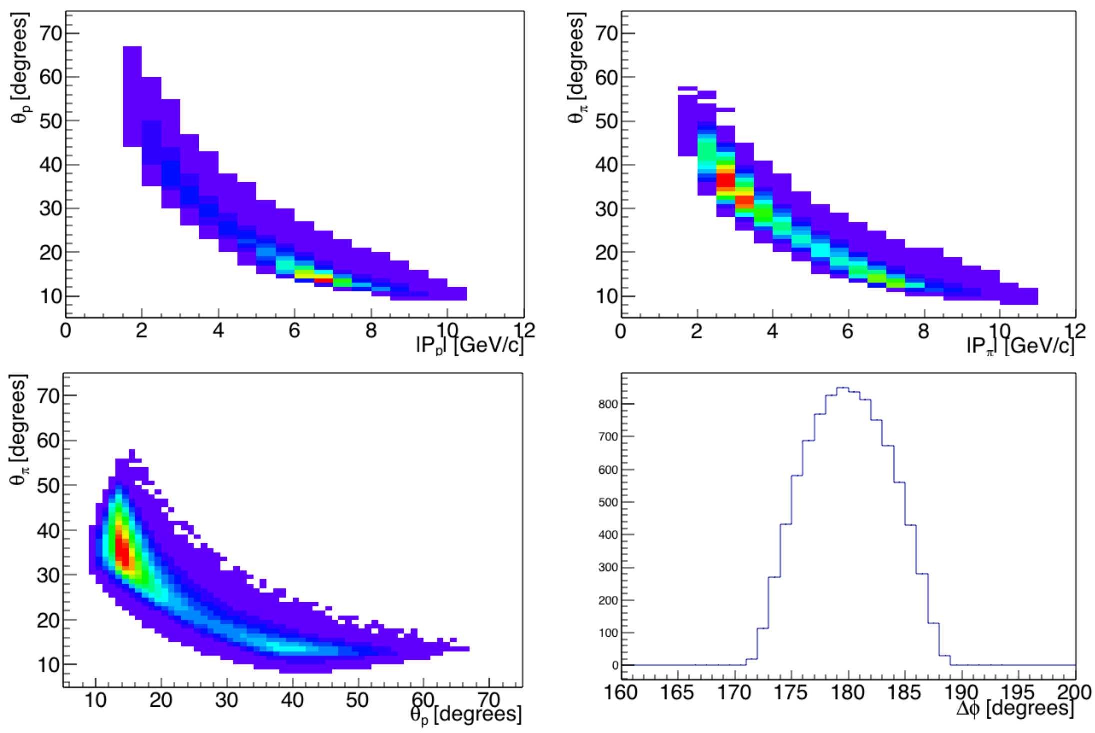

Figure 10: Same as Fig. 7 for all c.m. scattering angles.

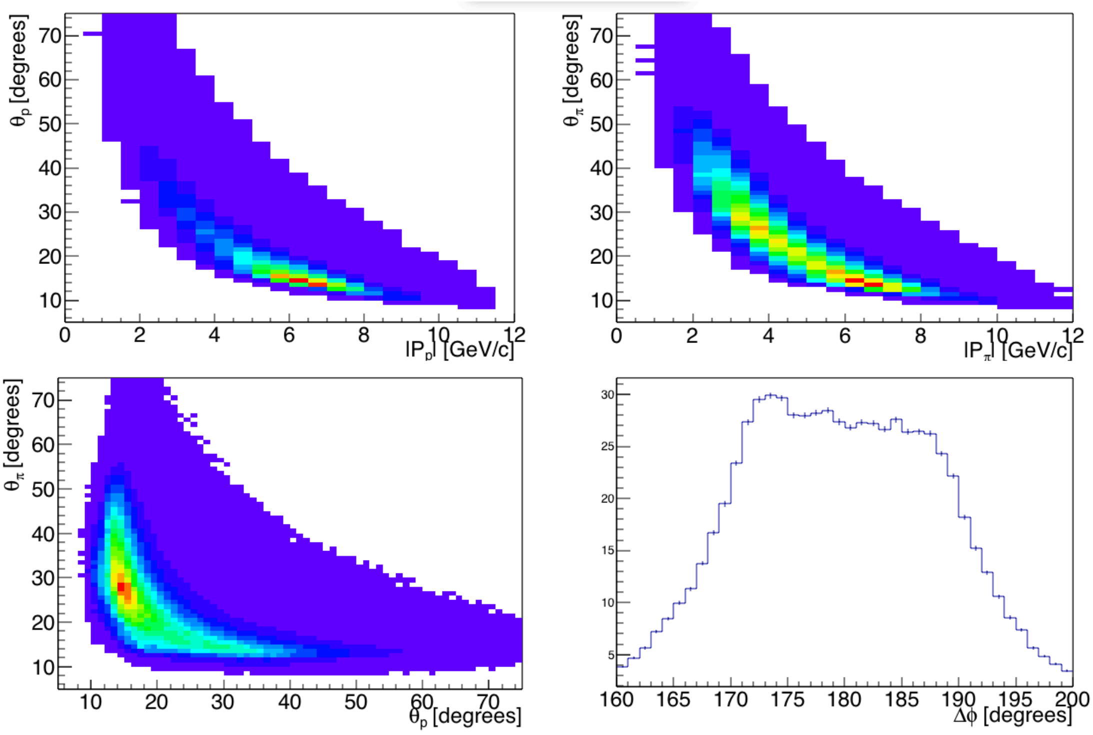

Figure 11: Same as Fig. 8 for all c.m. scattering angles.

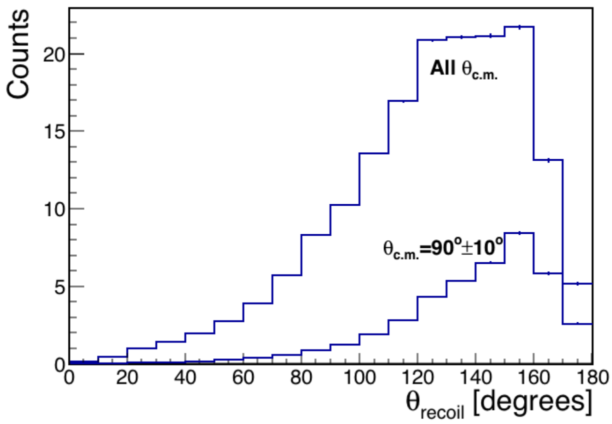

Figure 12: The angular distribution of the recoil nucleon when scattering off SRC pairs in the nucleus.

2.3. Acceptance and Detection Efficiencies

As mentioned, the GlueX detector was designed to have very large acceptance of high-momentum forward going charged particles emitted in the $A(\gamma, X)$ reaction. However, when scattering off SRC pairs we are interested in the coincidence detection of a recoil nucleon in the backward hemisphere (see Fig. 12). To study the acceptance of the recoil proton / neutron we ran Geant4 simulations of the GlueX detector for recoiling nucleons at a wide range of angles and recoil nucleon momenta.

Fig. 13 shows the acceptance and detection efficiency for recoiling protons for 3 different vertex positions – at the center and two ends of the 30 cm long hydrogen target. As can be seen, the detection efficiency is very high up to 140^{o} in the lab and can extend up to 160^{o} when the target is placed downstream. Fig. 14 shows the vertex reconstruction resolution, showing we can separate solid target foils with a distance of ~1 cm.

Fig. 15 shows the neutron detection efficiency as a function of the neutron momentum and angle. As can be seen, neutrons with momentum as low as ~ 200 MeV/c can be detected with efficiency of ~20% and even more than that, over a large range of recoil angles.

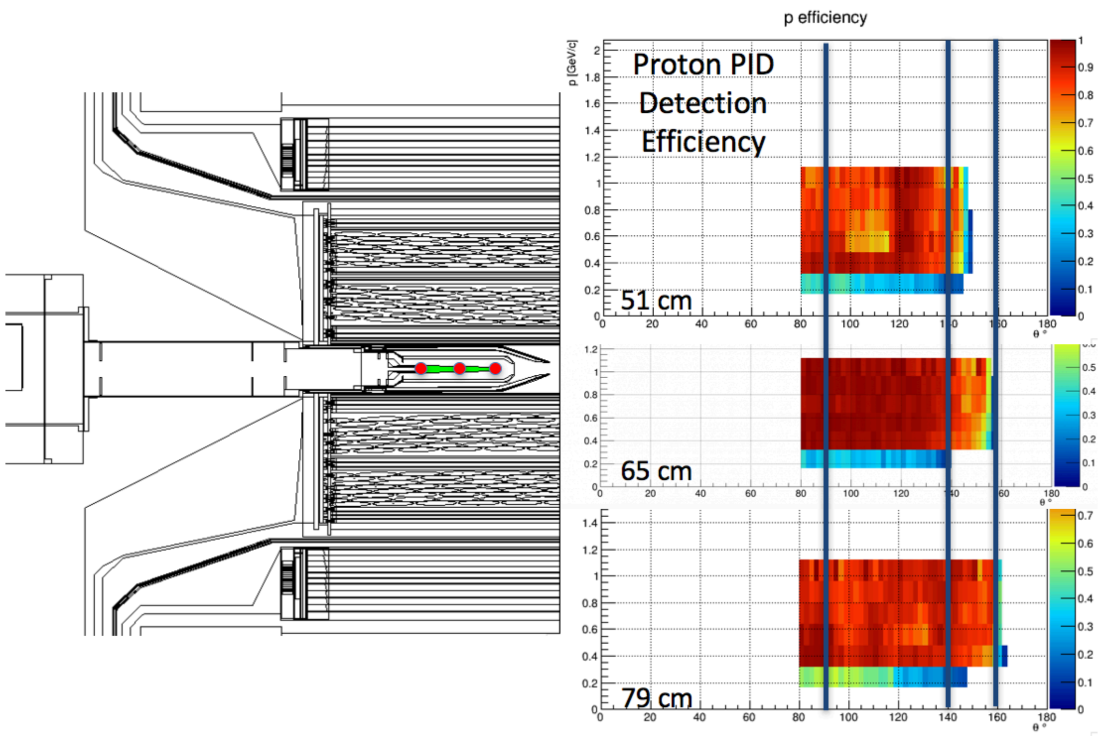

Figure 13: The detection efficiency for recoiling protons in GlueX as a function of the recoil angle and momentum for 3 different vertex locations.

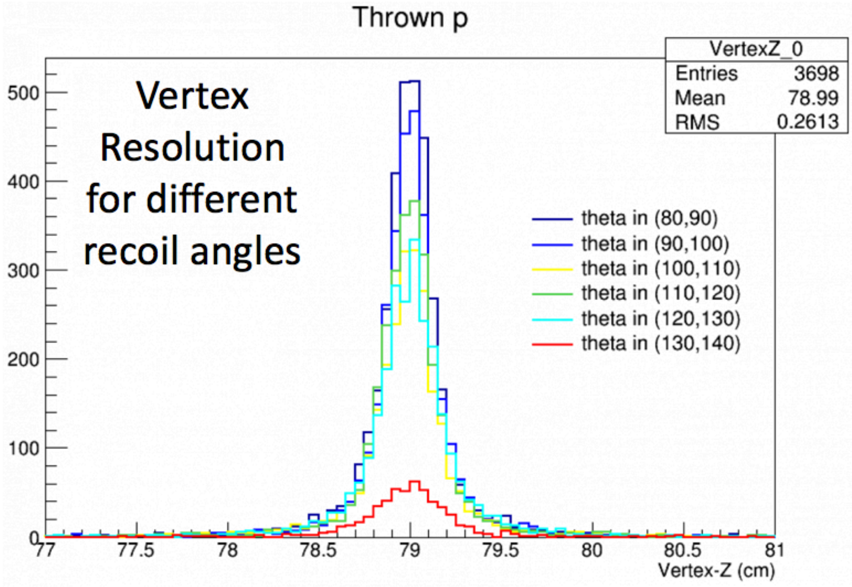

Figure 14: The vertex reconstruction resolution for recoiling protons a various recoil angles.

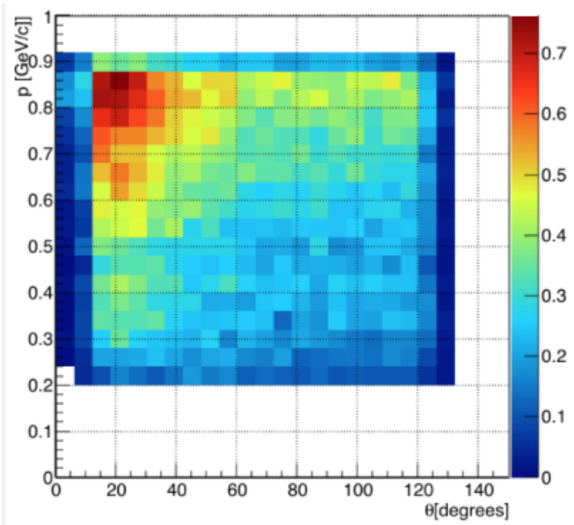

Figure 15: Same as fig. 13 for neutrons.

2.4. Rates

The rate calculations were done for the $\gamma n \rightarrow \pi^{-} p$ reaction, using the simulation presented in section 2.2. We assume 6 beam days with a photon flux of 5x10^{7} sec^{-1} on a 2 g/cm^{2} nuclear target. Based on the acceptance simulations presented in section 2.3 we assume 75% detection efficiency for the leading baryon and meson and 80% for the recoil nucleon. We also assume a reduction in the rate of 50% due to transparency of the leading baryon and meson and another 50% for the recoil nucleon. We note that we choose the $\gamma n \rightarrow \pi^{-} p$ reaction as it has one of the smallest cross-sections and therefore can serve as a lower bound on the expected number of events from the other reactions that will be measured simultaneously.

Figure 16 shows the *t* distribution for mean-field and SRC nucleons, with and without a cut on $\theta_{cm} = 90^{\circ} \pm 10^{\circ}$. As can be seen, without a cut on the c.m. angle, over 100 events per 1 GeV^{2} bin in *t* can be measured over a wide *t* range. For 90^{o} scattering and/or scattering off SRC nucleons the expected statistics is significantly lower but integrating over *t* still provides enough statistics to study the reactions of interest.

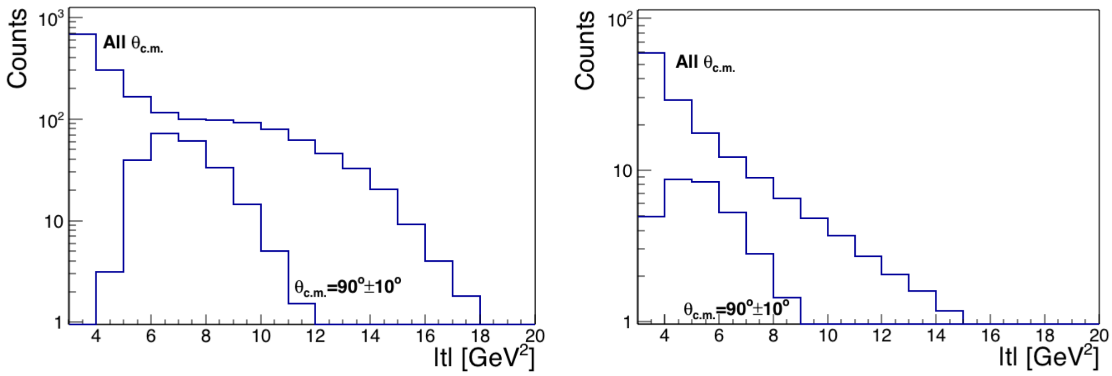

Figure 16: The count rate as a function of *t* for scattering off a nuclear target for mean-field (left) and SRC (right) nucleons.

3. Summary

We propose to measure the $A(\gamma,X)$ and $A(\gamma,XN_{recoil})$ reactions (where X represents a wide range of meson-baryon final states) for A = ^{2}H, ^{4}He, ^{12}C, ^{28}Si, ^{40}Ca, ^{48}Ca, and ^{54}Fe, ^{111}Ag, and ^{208}Pb using the maximum possible rate of coherent bremsstrahlung photons at E_e = 12 GeV (i.e. 8-9 GeV photons) and, if possible, also at E_e = 6 GeV during Hall-A parity-violation half energy per-pass running.

The data will be used to address the following issues:

- Possible nucleon decomposition modification in nuclei.
- Proton/neutron in asymmetric nuclei momentum tail.
- Transition from mean field to SRC (Migdal jump).
- The reaction of Quasi-Elastic scattering of a single nucleon in SRC pair.
- Discovering transition from resolved to unresolved photon dominance.
- CT for different particles and reactions.

We estimate this measurement will require a total 74 days at 12 GeV: 30 days with a deuteron target, 14 days with ^{4}He, and 30 days with nuclear targets. Pending scheduling constraints, we could benefit from an additional 30 days at 6 GeV divided in a similar way between the different targets.

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