# A respond to the TAC report on proposal PR12-11-107

1. *No time was allocated on Al dummy. The target cell length and shape are not specified. From "the beam requirement list", it seems that the target cell length will be about 3 cm. The Al window/wall contamination won't be the same at low and high x' values so it is crucial to take data on Al dummy to perform the ratio high x' over low x'.*

The TAC reviewer is correct. The Al window / wall contamination will need to be subtracted from the measured data. We expect to do the Al subtraction using curve fitting. We also propose to use a 10 cm rather than 3 cm target (see also answer to the question about signal-to-background below). The long time for the deuteron measurement (34 days) is due to the luminosity limit. Keeping the same nucleon luminosity we can run about a factor of 10 more beam current on a dummy target with a typical thickness of 0.005". Therefore, less than a day will be enough to get 50% of the total Al events that will be taken with the cell full, i.e. enough to fit and subtract. No extra beam time is requested.

2. *There is no discussion of electronics or readout scheme for the LAD, although the electronics needs would likely be similar to other Hall C large installation experiments. A frame/support for the LAD will be necessary.*

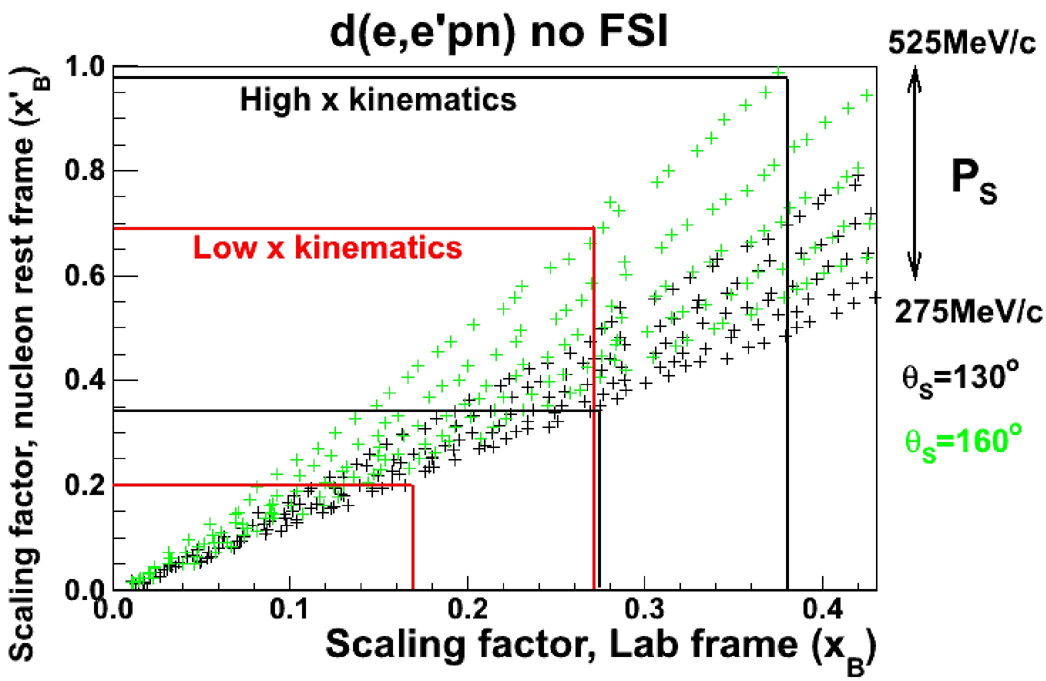
The number of PMTs in the planed LAD detector is not very different from the number of PMTs in the last triple coincidence SRC experiment E06-007. In the later we read each PMT to an individual ADC and TDC. Depending on the schedule, we hope to be able to use the same or similar electronics.

We need to design and produce a scattering chamber and a dedicated frame / support for the LAD counters. Since we plan to use the CLAS detectors with their sectors, the frame needs to hold in place the sectors as units and not the individual counters.

3. *The EMC region is defined with the x-bjorken variable (x between 0.3 and 0.6, approximately). From the table of kinematics (page 21), the x-bjorken values proposed in this measurement are 0.340 and 0.217, which is out of the EMC region. The use of the variable x' to define the EMC region (or the regions with large and small in-medium modification) is confusing.*

This is a physics question, not a technical question.

In this experiment we want to measure DIS on moving nucleons. $x_B$ is not Lorentz invariant, and the appropriate scaling variable to be used in the rest frame of the moving nucleon is $x_B$'. In the enclosed figure we show the relation between $x_B$ and $x_B$' for various recoil nucleon momenta and angles.




Note that $x_B$' is only a useful variable in the spectator approximation where there are no final state interactions and the momentum of the struck nucleon is just equal to and opposite the momentum of the detected recoil nucleon.

Note also that we actually do not propose to measure the EMC effect, we do not need or want to use same $x_B$ as the EMC. We have proposed a separate Letter of Intent to this PAC to measure the tagged EMC effect. In that case we will measure the cross section ratio of different nuclei as a function of $x_B$ for different recoil momenta.

4. *The experiment should take data on $LH_2$ at the same kinematics to establish the background from back-scattered nucleons not originating from a SRC.*

Our main method to measure the random coincidences is to create “mixed events” where the scattered electron in the spectrometer and the recoil nucleon in LAD are from two different events. For that procedure the deuteron production data can be used. We will also take some proton data as suggested by the TAC. No extra beam time is requested.

5. *The coincidence rates for accidentals are evaluated but the real/accidental ratios are not given.*

The signal to background ratio can be deduced from the statistical errors in the tables given in the proposal. Since we submitted the proposal we conclude that we can improve the signal to random coincidence (e,e'p) background by using a low mass front detector like a two plane GEM to reconstruct the target position using the emitted proton trajectory. By comparing the measured electron and proton target positions we can eliminate random coincidences with inconsistent target positions. We conservatively estimate that using two GEM detectors placed right outside the scattering chamber window and separated by 10 cm we can measure the proton interaction vertex with a resolution of 1 cm. This takes into account the effect of multiple coulomb scattering. Using a 2 sigma cut and a 10cm long target. we can improve the signal-to-background ratio by a factor of 2. For the purpose of this report we will be conservative and assume a factor of 4.  This factor is not included in the projected uncertainties listed in the proposal but included in the table below.

## Signal:background ratio for PR 12-11-107

d(e,e'p)

| $\alpha_s$ | **1.15-1.2** | **1.2-1.25** | **1.25-1.3** | **1.3-1.35** | **1.35-1.4** | **1.4-1.45** | **1.45-1.5** |
|---|---|---|---|---|---|---|---|
| **$x'_B>0.45$** | 1:1 | | 1:2 | | 1:2 | | 1:2 |
| **$0.25<x'_B<0.35$** | 3:1 | | 1:1 | | 1:1 | | 1:1 |

d(e,e'n)

| $\alpha_S$ | **1.15-1.2** | **1.2-1.25** | **1.25-1.3** | **1.3-1.35** | **1.35-1.4** | **1.4-1.45** | **1.45-1.5** |
|---|---|---|---|---|---|---|---|
| **$x'_B>0.45$** | 1:7 | | 1:8 | | 1:10 | | 1:7 |
| **$0.25<x'_B<0.35$** | 1:4 | | 1:4 | | 1:4 | | 1:4 |

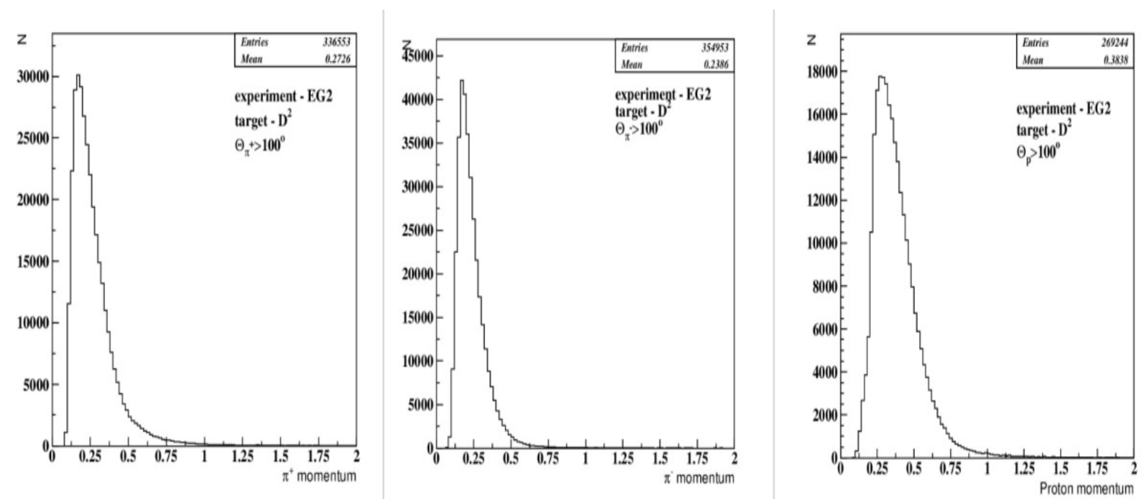
# Additional comments from the Independent TAC Review of PR12-11-107

1. *Proton identification relies on $\Delta E$ vs TOF cut. This will work if $\pi+$ background is low. At large angles number of pions will be orders of magnitude higher than protons. Out of time pions that undergo nuclear interaction in the scintillator counter can be misidentified as protons*

The singles protons rate was estimated in two ways, from an HRS measurement and from a measurement of the single protons rate on a single bar in the BigBite detector trigger plane. Note that the measurements were performed at 90 and $100^{\circ}$ and therefore should significantly overestimate the proton singles rate in the proposed LAD setup.

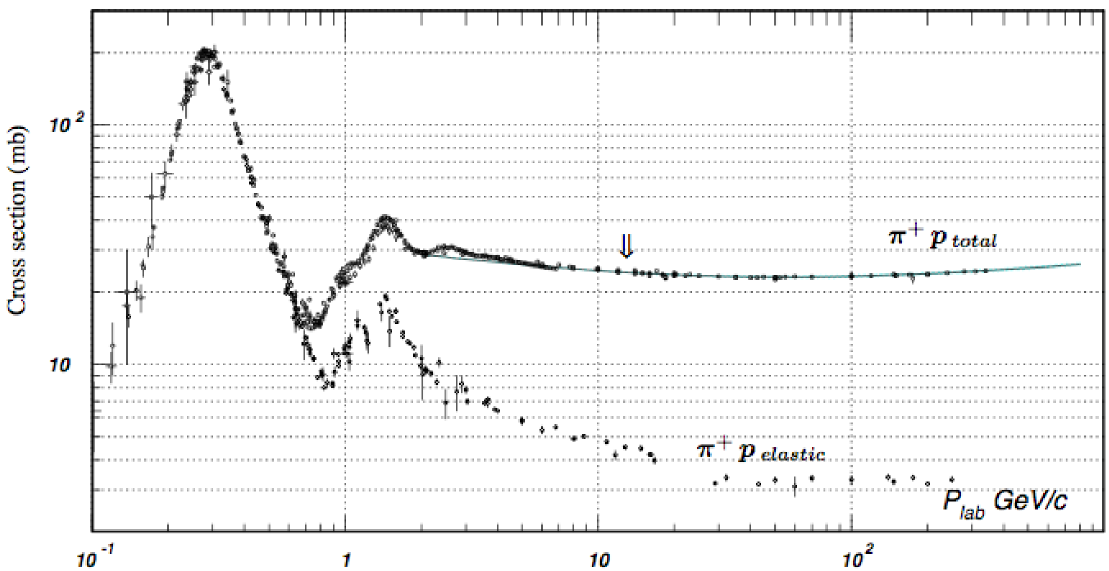
The two methods agreed. The BigBite detector PID was based on the energy deposited (E/dE) in the scintillator. Therefore it already includes contamination from any pions which underwent nuclear interaction in the scintillators. Because of the BigBite magnet acceptance, only pions with momentum above 250 MeV/c were taken into account.

The following plot shows the momentum distribution of protons, $\pi+$, and $\pi-$ from deuterium measured in CLAS integrated over all electron kinematics. At the lowest momentum (250 MeV/c) the ratio of minimum ionizing particle to protons is about 3:1.




This value is consistent with analysis of data collected with the BigBite. The figure enclosed show the energy deposit in one of the trigger plan E/dE scintintillators pair of Bigbite. The spectrometer was set at $92^0$ without a magnetic field. The trigger was on singles in BigBite. The data is from the last SRC experiment that run in Hall A at the first half of 2011. We apply a simple geometric cut to separate “minimum ionizing” from “protons”. For the different E/dE pairs of BigBite the ratio of “minimum ionizing” to “protons” is 2.5-3: 1.

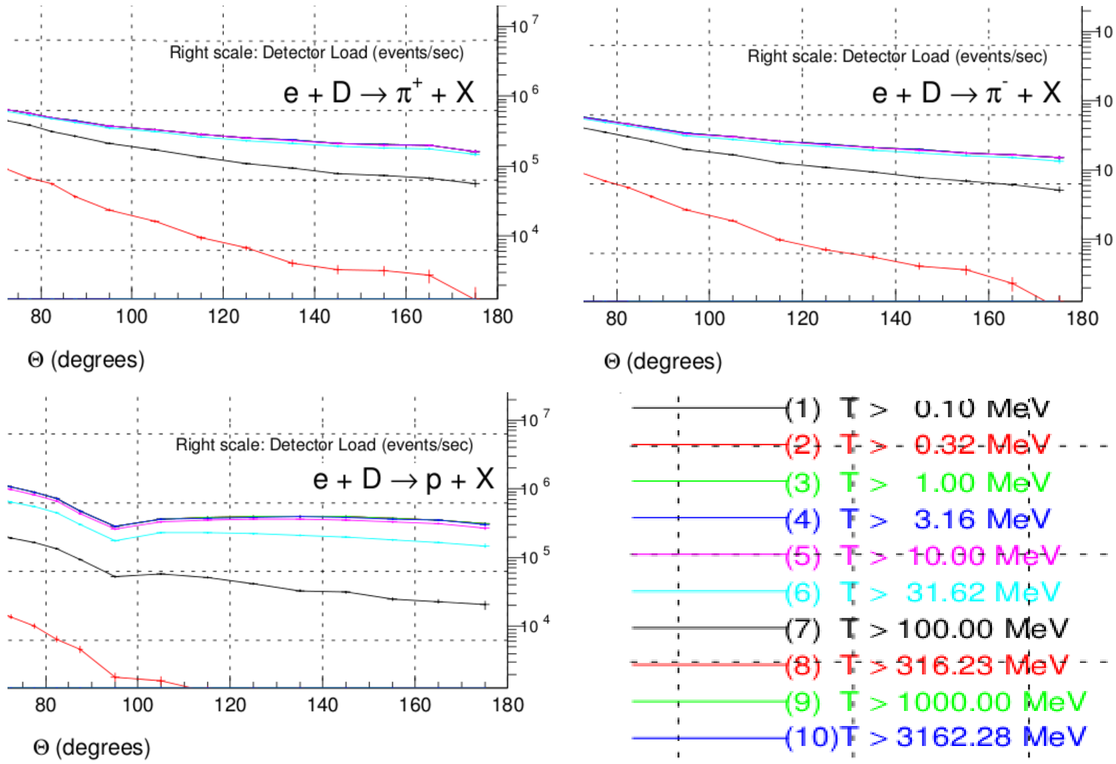
At low energies, backward pions originate in resonance decay the pion rate should not increase rapidly with decreasing momentum below the momentum cutoff in the figures. For the pions to create a relevant background they need to be absorbed and produce protons in the scintillators. The pion-nucleon cross section peaks at 300 MeV/c and drops as the momentum decreases (see plot below from the PDG). This will significantly decrease the contribution of lower momentum pions to the random proton rate. Therefore we do not expect the pion miss identification to increase significantly the random proton background estimate in the proposal.




In order to validate the analysis described above we also consulted simulation made by Pavel Degtiarenko. These simulations are the standard tool at JLab to calculate singles rates and shielding. The following plots show the pion and proton rates at the backward hemisphere. The calculations assumed a 1 μA, 11GeV, beam incident on a 10 cm deuteron target, and detector of 0.1 Sr.

First, one must note the small difference between the rate of pions with E>0.1MeV and E>31 MeV validates the assumption made in analysis of the CLAS and BigBite data above.

Second, the ratio of all pions rate (E>0.1MeV) to the relevant protons rate (E>31 MeV, P>240 MeV/c) is no more then 5:1. When considering the convolution of this 5:1 ratio with the (pi,p) cross section we get another indication that the contribution of the pion BG to the single protons rate should not be significant.




Finally, one must note that the signal-to-background ratio for (e,e'p) is relatively large (1:1 to 1:2) and therefore even a modest contribution from single π+ will not damage the measurement.

*2. Neutron identification is very much in question, there are no details or simulations on how beam related background will effect neutron identification. Accidental to real ratio in this case is very high. One can check CLAS "straight track runs" (with torus turned off) to estimate background rates on backward TOF counters and to check neutron identification.*

Neutrons were detected using the proposed LAD scintillators as part of the CLAS6 program. The analysis is detailed in CLAS note 2008-103. In this analysis the neutrons are defined as uncharged particles (i.e. no signal in the CLAS6 wire chambers) which deposited over 5 MeVee in the scintillator counter. The demand for energy deposit of above 5 MeVee was used to eliminate BG from beam related, low energy photons.

In Hall-A SRC experiments E07-006 and E01-015 neutrons were detected in HAND after passing through a thin (1 inch) lead wall and leaving a signal greater than 5MeVee in a 10 cm thick scintillator. This detector vetoed charged particles by demanding that there was no hit in a scintillator bar placed before the bar that was struck.

In both cases the neutron identification was successful and their signal was clear. For this experiment we plan to utilize the experience of both halls and demand a double veto. The veto will consist of no signal in either the GEM detectors or in the first scintillator layer (which is 5 cm thick and is used for proton detection). We will use the same 5 MeVee threshold on the neutron bars to eliminate low energy photons. Past experience with neutron identification using scintillators in both Hall A and Hall B shows that these techniques work.

In the Hall-A SRC experiment the Signal-to-background ratio was about 1:5. While the expected (e,e'n) signal-to-background ratio in this experiment (about 1:4 to 1:8) is not as good, the expected signal is larger by more than an order of magnitude. We included this background in the estimation of the statistical error of the (e,e'n) signal. The statistical significance of the signal is still clear and we think that the signal can be analyzed.

We would also like to note that, as mentioned in the proposal, we are considering the use of a 15 MHz pulsed beam (one pulse every ~64ns). Depending on the exact width of each pulse, this will allow the random coincidence window of the neutrons to be narrower then the 60ns coincidence width defined by the kinematics of the proposal. This is expected to reduce the (e,e'n) random coincidence rate significantly.

3. The range of a 50 MeV proton is about 2.3 g/cm2. If there is to be no more than ~1 g/cm2 of Aluminum in the path, the thickness of windows and other structures cannot exceed 4 mm. The beam-left location of the scintillator array avoids the impediment by the existing target heat exchanger. All the cryogenic target cells used in Hall C to date have a re-entrant inlet tube which interferes somewhat with large angle charged particle acceptance. It looks like the existing 4cm tuna-can cells are a fair match to the proposed experiment, but the acceptance cuts off somewhere around 165 degrees. The collaboration should consult drawings

The referee is correct and we plan on minimal mass (scattering chamber window, low mass GEM detector and air) on the way of the proton from the target to the LAD front detector layer. We assume we can use a scattering chamber that is similar to that of the BigBite detector used in Hall-A. The scattering chamber used in the $pi^0$ production experiment (E****) used a 75um thick window, made of Ti. Including a Hall-A style deuterium target (see comment below) and two low mass GEM detectors we estimate about 0.35 – 0.4 $g/cm^2$ of material between the target and the scintillators. 4 m of air will add another 0.4 $g/cm^{2,}$ for a total of about 0.75 – 0.8 g/cm2. We are also considering adding a He bag, like to one used in the $pi^0$ production experiment, to reduce the multiple scattering in the air on the way to LAD.

We prefer to use a 10cm long, Hall-A style, finger target and not a tuna-can target. The use of such a target will reduce the path length inside the target which will reduce the signal:BG ratio and improve the GEM vertex reconstruction resolution. We consulted the target group and they see no challenge in producing such a target with large backwards angles opening on one side of the beam.