Q^2 Dependence of Nuclear Transparency for Incoherent ρ^0 electroproduction

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Abstract

Measurements of exclusive incoherent electroproduction of $\rho^0(770)$ meson from ${}^2D$, ${}^{12}C$, and ${}^{63}Cu$ targets up to Q^2 = 4 GeV^2 are proposed using the CLAS detector. The objective of these measurements is to determine the Q^2 dependence of the nuclear transparency ratio for the two nuclear targets : ${}^{12}C$ and ${}^{63}Cu$ at fixed coherence length of quark-antiquark fluctuations of the virtual photon. A sizeable rise of the nuclear transparency is predicted and can be measured in this experiment. A relatively large increase of the nuclear transparency can be considered as a signature of the onset of color transparency.

1 Introduction

One of the major goals of Jefferson Laboratory (JLab) is to explore and study the interface between the nucleonic picture of the strong interaction and the partonic one. Although the standard nuclear models are successful in reproducing the overall picture of hadrons interacting at large distances, and QCD is convincing in the description of the quarks interacting weakly at short distances (Perturbative QCD), the physics connecting the two regimes is almost non existent. When probing distances comparable to those separating the quarks, classical nuclear physics should break down at some point, yet the nucleonic picture still describes many features of the strong interaction. The alternative is to look for the onset of experimentally accessible phenomena which are naturaly predicted by QCD. Color transparency (CT) could be a potential candidate. Its basic concepts imply that in exclusive hard processes at large momentum transfer (Q), the hadron has more chance to escape intact from a nuclear target if its wave-function fluctuates into a configuration which contains only valence quarks with small transverse separation. This small size object should lead to a vanishing absorption when it propagates through the nucleus. In this proposal, we hope to observe a clean signal of the onset of CT. By studying the onset of color transparency, one could improve our understanding of the dynamics of bound states in QCD and therefore help to build a detailed picture of photon and electron interactions with nuclei at intermediate energies.

We propose to measure the Q^2 dependence of the nuclear transparency ratio in incoherent diffrative ρ^0 electroproduction on carbon and copper, for fixed coherence lengths. Two energies of the electron beam at 6 and 4 GeV are proposed to be used. The Q^2 range is up to 4 GeV^2. Measurable effects of about 40$\%$ are predicted for the covered Q^2 region. The proposed experiment seeks to measure the nuclear transparency of the ρ^0 meson with 8% to 15% uncertainties, dominated by systematics in the low Q^2 region and by statistics at high Q^2.

2 Physics motivations

The color transparency phenomenon illustrates the power of exclusive reactions to isolate simple elementary quark configurations. For a hard exclusive reaction such as vector meson electroproduction on the nucleon, the scattering amplitude at large momentum transfer is suppressed by powers of Q^2 if the hadron (vector meson in this case) contains more than the minimal number of constituents. This is derived from the QCD based quark counting rules. Therefore, the hadron containing valence quarks only, participates in the scattering. Moreover, each quark, connected to another one by a hard gluon exchange carrying momentum of order Q, should be found within a distance of order $1/Q$. Therefore, at large Q^2 one selects a very special quark configuration where all connected quarks are close together, forming a small size color neutral configuration called *Point Like Configuration* (PLC). During a formation time $\tau_f = 2\nu/(M_{v'}^2 - M_v^2)$, where M_v is the mass of the vector meson in its ground state and $M_{v'}$ its first orbital excitation mass, the *mini hadron* evolves to a normal hadron. Such an object is unable to emit or absorb soft gluons. Therefore, its strong interaction with the other nucleons becomes significantly reduced, and then the nuclear medium becomes more transparent. Consequently, the signature of CT is an increase in the nuclear transparency T_A with increasing hardness of the reaction. T_A is defined as the ratio of the measured exclusive cross section to the cross section in absence of initial and final state interaction (ISI and FSI). It can be measured by taking the ratio of nuclear per-nucleon (σ_A/A) to free nucleon (σ_N) cross sections :

$$T_A = \frac{\sigma_A}{A\sigma_N} \tag{1}$$

A number of experiments have searched for an increase in the nuclear transparency. Unfortunately only few of them were able to claim confirmation of CT. The first experiment to investigate CT was performed by Carroll *et al.* [1] at Brookhaven National Laboratory. Quasielastic (p,2p) scattering from each of several nuclei was compared to pp elastic scattering in hydrogen at incident proton momenta of 6, 10, and 12 GeV/c. Its results do not support a monotonic increase in transparency with Q^2 as predicted by CT : the transparency increases for Q^2 from 3 to 8 GeV^2, but then decreases for higher Q^2, up to 11 GeV^2. This subsequent decrease was explained as a consequence of soft processes that interfere with pertubative QCD in free pp scattering but are suppressed in the nuclear medium [3]. Due to the simplicity of the elementary electron-proton interaction compared to proton-proton one, the quasi-free A(e,e'p) reaction was suggested as an alternative [2-5]. Unfortunately, both the SLAC [6] and JLab [7,8] experiments failed to produce evidence of CT even for the Q^2 values as large as 8 GeV^2. The clearest signal of CT was observed in the E791 experiment [9] at Fermilab. The A-dependence of the diffractive dissociation into di-jets of 500 GeV/c pions scattering coherently from carbon and platinum targets was measured. It was found that the cross-section can be parametrized as $\sigma = \sigma_0 A^\alpha$, with $\alpha = 1.6$. This result is quite consistent with theoretical calculations [10-12] including CT effects and is obviously inconsistent with a cross-section proportional to $A^{2/3}$ which is typical of inclusive π-nucleus interactions. Another Fermilab experiment, E665 [13] reported interesting indications of CT using a 470 (GeV/c) muon beam. Exclusive diffractive ρ-meson production from nuclear targets was used to determine the nuclear transparency. The increase of the nuclear transparency with Q^2 was only suggestive of CT because the statistical precision of the data was not sufficient.

CT effects at moderate energies are more problematic than they are at high energies. One should deal in this case with other mechanisms that contain no explicit QCD dynamics and which may mock the CT signal. The experimental studies of CT were mainly focused on the quasi-elastic electron scattering (e,e'p) process. In these measurements inelastic corrections could mock [14] the CT signal. The existence of such processes was confirmed by the measurements of the total cross sections of neutron [15] and neutral K-meson [16] interactions with nuclei. Due to these inelastic corrections, the cross-section is smaller, i.e. the nuclear medium is more transparent than is expected by the Glauber approximation. This effect increases with the ejectile energy. Thus, it will also increase with Q^2 because the energy $\nu = Q^2/2m_N$ and Q^2 are correlated in the quasi-elastic peak. The first order inelastic corrections has been estimated in Ref.[14]. It was found that the growth of nuclear transparency with Q^2 in quasi-elastic electron scattering off nuclei could imitate the onset of CT up to $Q^2 \sim 20$ GeV^2.

Exclusive incoherent electroproduction of vector mesons off nuclei has also been suggested [17] as a sensitive way to detect CT. In these processes, a fluctuation of the virtual photon gives rise to a quark-antiquark ($q\overline{q}$) pair that travels through the nuclear medium evolving from the initial state, with Q^2 dependent size (the transverse size of the hadronic fluctuation is $r_\perp \sim 1/Q$), to develop the vector meson detected in the final state. Therefore increasing the photon virtuality Q^2, one can squeeze the size of the produced ($q\overline{q}$) wave packet. The hadronic structure of high energy photons was realized back in the 1960's (for review see [18]). In the laboratory frame, the photon fluctuation can propagate over a distance l_c known as the *coherence length* . The coherence length can be estimated relying on the uncertainty principle and Lorentz time dilatation as $l_c = 2\nu/(Q^2 + M^2_{q\overline{q}})$, where ν is the energy of the photon in the laboratory frame, $-Q^2$ is its squared mass and $M_{q\overline{q}}$ is the mass of the ($q\overline{q}$) pair. In the case of exclusive ρ^0 electroproduction, the mass of $q\overline{q}$ is dominated by the ρ^0 mass. The produced small size colorless hadronic system will then propagate through the nuclear medium with reduced attenuation because its cross section is proportional to its size ($\sigma(r) \propto r^2$). The effect of the nuclear medium on the particles in the initial and final states can be characterized by the nuclear transparency. Our ultimate goal is searching for a rise of T_A with Q^2 as a signal for the onset of CT. However, one has to be careful about all the other effects that can imitate this signal. Indeed, the HERMES experiment [19] has shown that T_A increases when l_c varies from long to short compared to the size of the nucleus. This is due to the fact that the nuclear medium seen by the ($q\overline{q}$) fluctuation becomes shorter. Thus the ($q\overline{q}$) interacts less. This situation occurs when Q^2 increases at fixed ν. This so called *coherence length effect* (CL) must be under control to avoid mixing it with the CT effect.

We propose to measure the nuclear transparency for exclusive incoherent ρ^0 electroproduction on ^2D, ^{12}C, and ^{63}Cu targets up to Q^2= 4 GeV^2 and for fixed l_c values; l_c = 0.4 fm and l_c = 0.5 fm. Binning the data in a way which keeps l_c constant represents a simple prescription to eliminate the CL effect from the Q^2 dependence of the nuclear transparency. Moreover, because the chosen values of l_c are shorter than the mean free path of the vector meson in the nuclear medium, it is obvious that there is no nuclear shadowing in the initial state. By isolating the CL effect, the Glauber model predicts no variation of T_A with Q^2. Following a recent work by Kopeliovich and collaborators [20], an important increase of the nuclear transparency with Q^2 is predicted as a signal for the onset of CT. The suggested reaction was exclusive incoherent ρ^0 electroproduction on nuclei for fixed l_c values. The authors have developed a quantum mechanical approach based on the light cone QCD Green function formalism. This formalism naturally incorporates the inter-

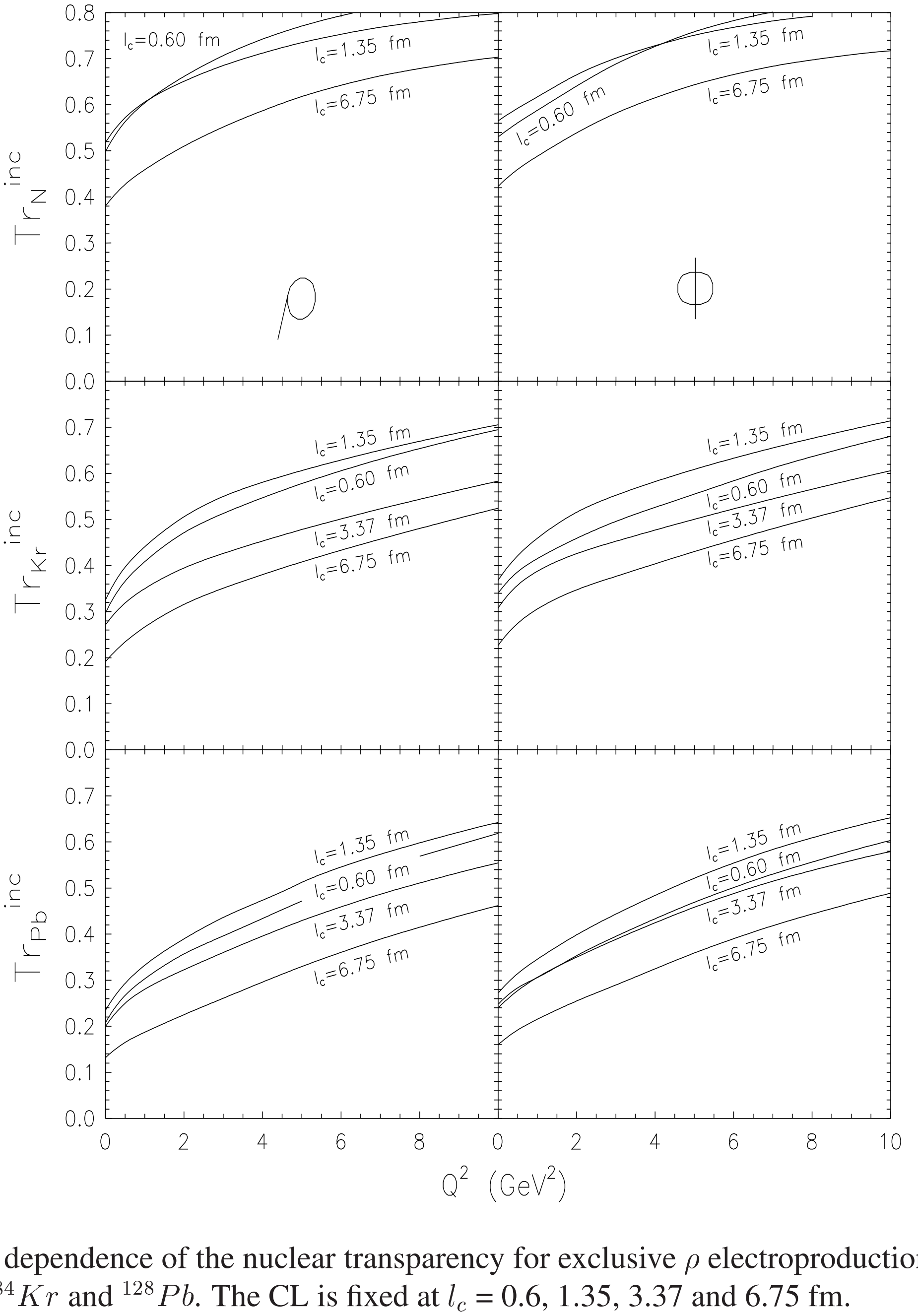

Figure 1: Q^2 dependence of the nuclear transparency for exclusive ρ electroproduction on nuclear targets ^{14}N, ^{84}Kr and ^{128}Pb. The CL is fixed at l_c = 0.6, 1.35, 3.37 and 6.75 fm.

ference between the CL effect (ISI) and CT effect (FSI). Due to quark-hadron duality, it becomes equivalent to the full multichannel problem in the hadronic presentation. These calculations have succeeded in describing the coherence length dependence of the nuclear transparency reported by the HERMES collaboration [19] and are also in good agreement with the FNAL E665 measurements [13].

In Fig.1, we show the predicted nuclear transparency [20] ratio as a function of Q^2 for incoherent ρ^0 electroproduction on nitrogen and krypton at fixed l_c values. As one can see, we would obtain a measurable effect of at least 30% for the Q^2 range up to 4 GeV^2. The proposed measurements can detect these large effects without ambiguity if they exist. It is the first time dedicated fixed l_c measurements are proposed. Such an experiment is important to disentangle the CL effect from an eventual onset of CT. If the proposed measurements confirm the predicted effect, it will be important to study the kinematic conditions for which exclusive vector meson electroproduction is dominated by the contribution of small size configurations. Informations on the mini-hadron evolution to its normal size and its reduced final state interaction with a spectator hadron can also be obtained. In any case these measurements are important to understand the dynamics of vector meson production in the nuclear medium and to study the microscopic structure of hadrons where color effects probably have an important role.

3 The experiment

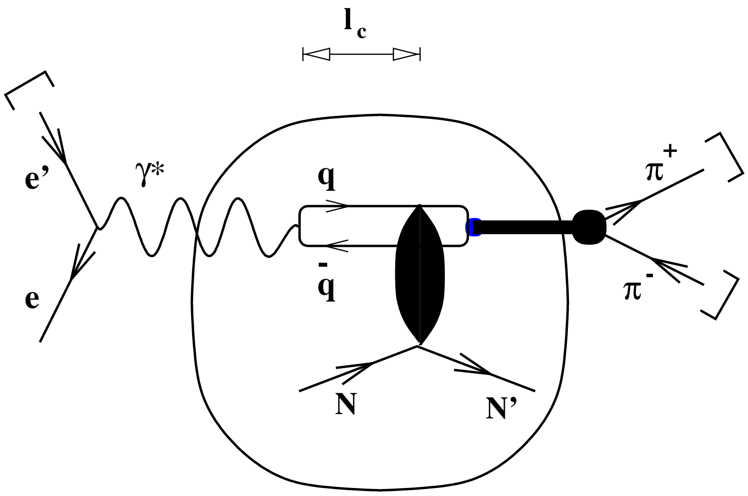

Figure 2: Exclusive leptoproduction of the ρ^0 meson.

We propose to measure the nuclear transparency ratio, $T_A = \sigma_A / A\sigma_N$, for incoherent ρ^0 electroproduction on two nuclear targets (A = ^{12}C and ^{63}Cu) as a function of Q^2.
In the next section 3.1, we describe the reaction and the kinematics that will be used to study the

nuclear transparency. The estimated count rates considering the acceptance of the CLAS detector will be presented in section 3.2.

3.1 Kinematics

The schematic of the reaction is given in Figure 2 : The incident electron scatters off the target nucleus and exchanges a virtual photon. The photon interacts with one of the nucleons inside the nucleus and eventually produces a ρ^0 meson. The ρ^0 decays into two pions. We propose to perform these measurements at Hall B with electron beams of 6 GeV and 4 GeV at maximum luminosity of $(5 \times 10^{33} cm^{-2} s^{-1})$. Three targets will be used : deuterium, carbon, and copper. The scattered electron will be detected to determine Q^2. The coincident detection of the two pions will allow the identification of ρ^0 particles using their reconstructed invariant mass. We also propose to measure ρ^0 photoproduction to complete our measurements with a point at $Q^2 = 0$. For this purpose, a tagged photon beam of 1.7 to 2.2 GeV at maximum flux $(0.8 \times 10^7 \gamma/s)$ will be used on the same set of targets.

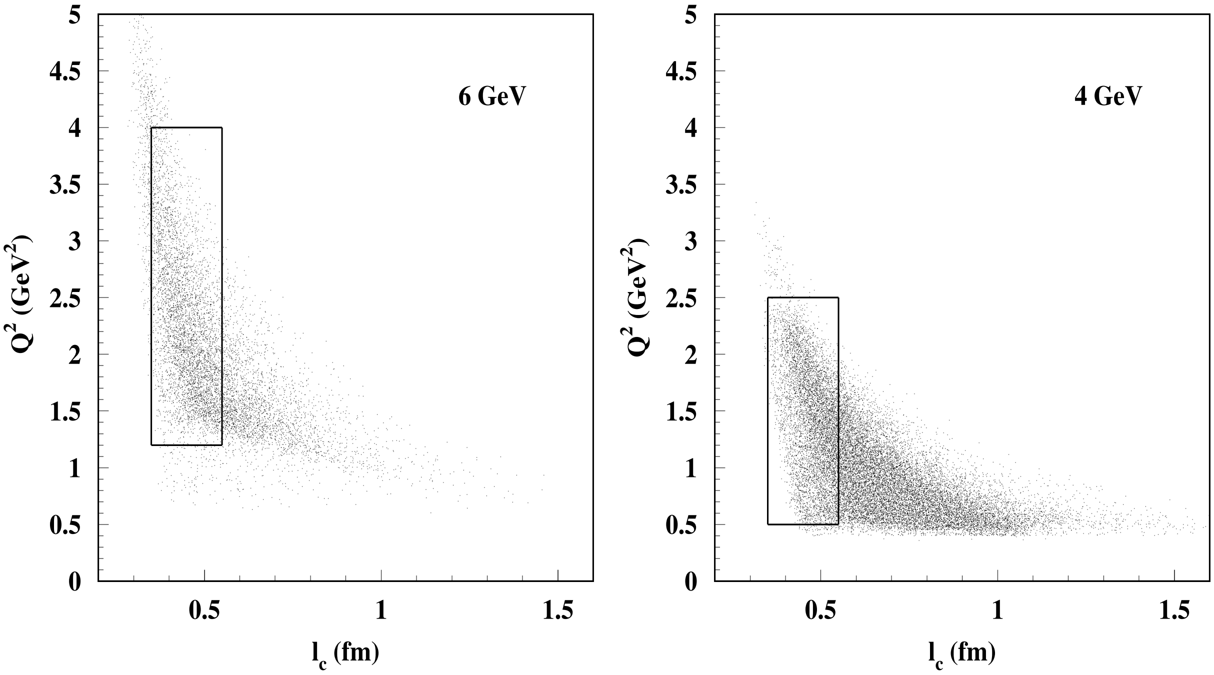

Figure 3: $l_c - Q^2$ correlation for the two electron beam energies.

Since the coherence length effect can imitate the color transparency effect, we will study the Q^2 dependence of T_A at fixed l_c values. Although our measurements will cover a coherence length range from 0.3 to 1.5 fm, none of the l_c values covers the whole range in Q^2. Therefore, we need to consider at least two values of the coherence length, l_c = 0.4 fm covering high Q^2 region from 1.5 to 4. GeV^2 with reasonable count rates, and l_c = 0.5 which covers Q^2 from 0.5 to 3 GeV^2. The bins in l_c are 0.1 fm wide centered at 0.4 and 0.5 fm. For l_c = 0.4 fm, six Q^2 bins are considered, 0.5 GeV^2 wide, each centered at 1.5, 2, 2.5, 3, 3.5 and 4 GeV^2. For l_c equal to 0.5 fm, five Q^2 bins centered at 0.75, 1.25, 1.75, 2.25 and 2.75 GeV^2 are considered. In the letter of intent we have submitted to PAC21, we have only considered a 6 GeV electron beam. After analyzing 4 GeV carbon data, we realized that at 6 GeV, the fiducial cuts necessary for CLAS analysis make the lowest available Q^2 of 1.25 GeV^2. Figure 3 shows the nessecity to use 4 GeV electron beam to go down to Q^2 of 0.75 GeV^2.

3.2 Count rates

A new event generator of ρ^0 electroproduction from both protons and nuclear targets has been implemented. The three independent kinematical variables : W, Q^2 and the momentum transfer, t, are generated according to their experimental distributions. W and Q^2 are generated according to the flux of virtual photons $\Gamma(W, Q^2)$ exchanged between the incident electron and the target :

$$\Gamma(Q^2, W) = \frac{\alpha}{8\pi^2} \times \frac{W}{ME^2} \times \frac{W^2 - M^2}{MQ^2} \times \frac{1}{1-\epsilon} \tag{2}$$

where M is the mass of the target. E and E' are respectively the energies of incident and scattered electrons, $\nu = E - E'$ is the energy of the virtual photon, and the variable $\epsilon = [1 + 2(Q^2 + \nu^2)/(4EE' - Q^2)]^{-1}$ is its polarization. The momentum transfer, t, is generated according to the experimental differential cross section $\frac{d\sigma}{dt}$ reported in ref.[21] and fitted to the exponential form :

$$\frac{d\sigma}{dt'} = A \exp(-b(W, Q^2) \times t'), \tag{3}$$

where $t' = |t - t_{min}|$, and t_{min} is the minimum value of t. The values of the slope $b(W, Q^2)$ measured for different W and Q^2 bins have been considered. Fermi momentum of nucleons inside the nucleus has been taken into account. The momentum of the struck nucleon is generated inside the corresponding Fermi momentum sphere of radius P_F. Experimental values of P_F [22] have been used. The generator considers also the decay of ρ^0 into a pair of pions $\pi^+\pi^-$. Pion angles are generated assuming s-channel helicity conservation.

Using the generator's output as input to the fast simulation code of the CLAS detector, FASTMC [23] and taking the CLAS torus magnetic field at half its maximum value, we have been able to study the acceptance and efficiency of CLAS to detect the three particles : the scattered electron, and the ρ^0 decay pions $\pi^+\pi^-$. Before studying the acceptance, kinematical cuts have been applied to well identify the reaction of interest. We use W > 2 GeV cut, to avoid the resonance region, $z = \frac{E_\rho}{\nu} > 0.8$, to select the elastic process, and $|\Delta E| < 0.2$ GeV cut to reduce the contamination from non-exclusive events.

$$\Delta E = \nu - E_\rho + t/2M_p \tag{4}$$

ΔE is the energy missing from the $\pi^+\pi^-$ pair due to the creation of any additional final state particles (excitations of the recoil nucleus don't affect ΔE within the resolution). The cut on ΔE

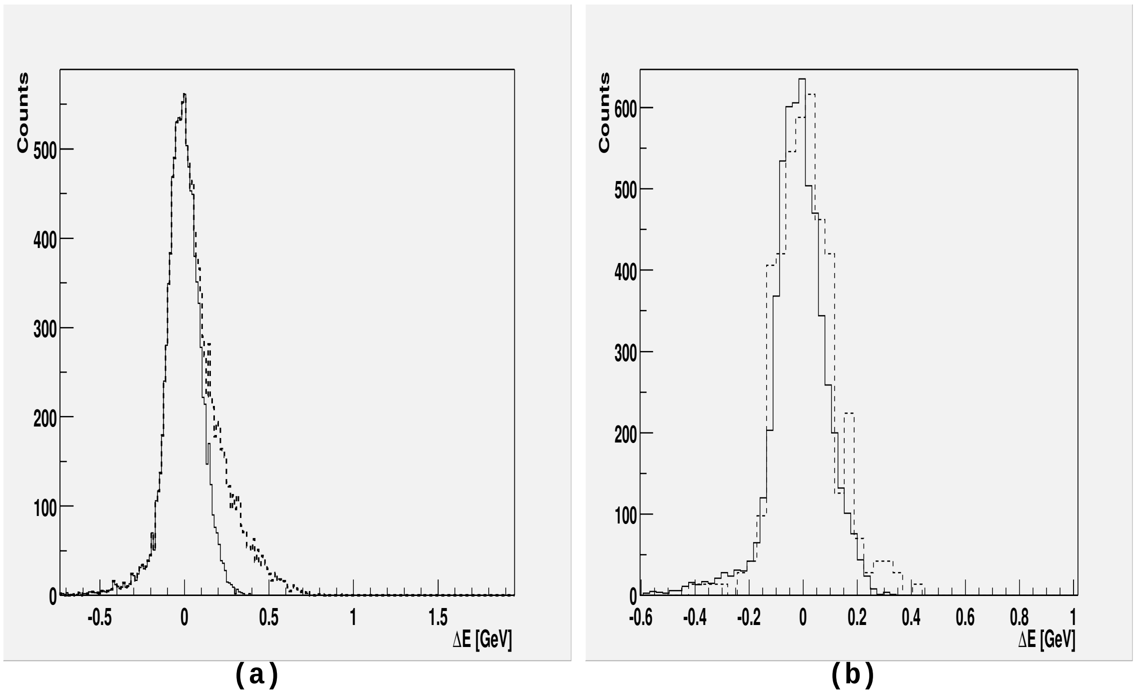

Figure 4: (a) : Dashed curve corresponds to ΔE from 4 GeV electron beam on Carbon in our Kinematic region (t' and W cuts). The solid curve is after $z > 0.8$ cut. (b) : Solid curve corresponds to ΔE from 4 GeV electron beam on Carbon in our Kinematic region (t', W and z cuts). The dashed curve corresponds to ΔE from GSIM with a pure exclusive diffractive ρ^0 electroproduction generator. Note that the GSIM curve was scaled by a factor 14 to match the amplitude of the data.

is closely related to the cut $z \simeq 1$ but has the advantage that it includes the correction for the kinetic energy $-t/2M_p$ of the recoil nucleon and that the inelastic threshold $\Delta E = m_\pi + m_\pi^2/2M_p$ is independent of ν. One could expect that the z and ΔE cuts would be equivalent but as you can see from figure 4.a, the solid curve corresponding to ΔE from 4 GeV CLAS carbon data with $z > 0.8$ cut is much more cleaner than the one (dashed curve) without it. In figure 4.b, the solid curve corresponds to the 4 GeV carbon data with Z cut and the dashed one is obtained from the GSIM CLAS monte carlo with a pure exclusive ρ^0 electroproduction generator as input. The agreement between the data and the simulation is a good indication of our ability to identify the exclusive channel. The cut $-t' < 0.5$ GeV^2 has also been used to select the diffractive process. To exclude coherent production, we use $-t' > 0.1$ GeV^2 cut. The acceptance for a given (l_c, Q^2) bin is calculated by :

$$Acc(l_c, Q^2) = \frac{N_{acc}(l_c, Q^2)}{N_{gen}(l_c, Q^2)}, \tag{5}$$

where N_{gen} and N_{acc} are respectively the number of generated and accepted events belonging to this (l_c, Q^2) bin. CLAS acceptance for different l_c bins (left graph) and Q^2 bins (right graph) and for the two electron beam energies are shown in Figure 5. Using the output of FASTMC and ρ^0 electroproduction cross sections, $\sigma(W, Q^2)$, measured on hydrogen [21], we have been able to estimate count rates for the chosen bins in l_c and Q^2. In addition to the Fermi momentum considered in the generator, both the nuclear transparency of the nucleus to ρ^0 and the absorption

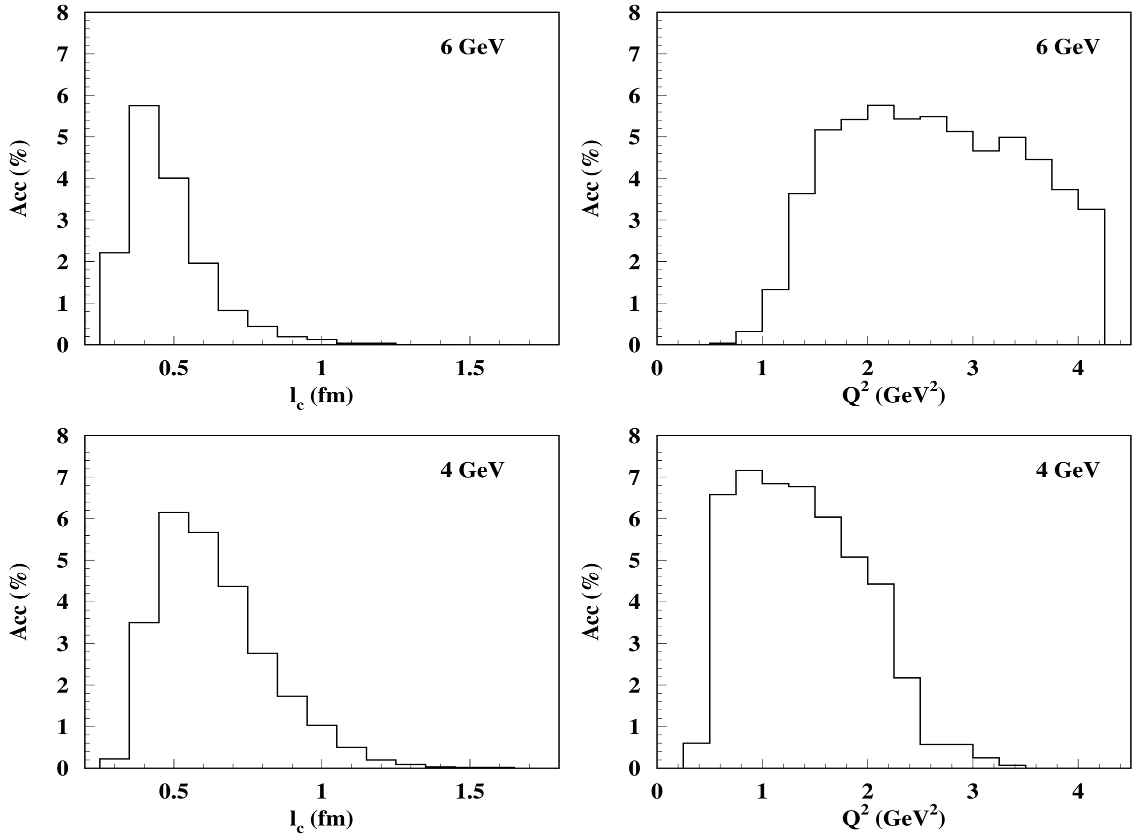

Figure 5: Acceptance for different bins in l_c and Q^2

of its decay pions inside the nucleus have to be taken into account in the estimation of the count rates. To consider the transparency, the value of the cross section is scaled by the corresponding value of the transparency T_A. The loss of the decay pions by interaction inside the nucleus has been estimated using the intranuclear cascade model ISABEL [24] (see section (4.1) for details). For 6 GeV electron energy, we have used a run time of 10 days on each target to have reasonable statistical accuracy at high Q^2. For the 4 GeV part, we have used 5 days run time for each target. For the point at $Q^2 = 0$, using the ρ^0 photoproduction cross section on hydrogen measured by Eisenberg *et al* [25], one day of 1.7-2.2 GeV photon beam on each target gives sufficient statistics. The following tables summarize the expected statistical uncertainties on the number of ρ^0 particles to be detected for l_c = 0.4 fm and l_c = 0.5 fm at different Q^2 bins, for the two beam energies and for the three targets. The following tables are for l_c = 0.4 fm and l_c = 0.5 fm.

Target \ Q^2 (GeV^2)	1.5 ± 0.25	2.0 ± 0.25	2.5 ± 0.25	3.0 ± 0.25	3.5 ± 0.25	4.0 ± 0.25
Deuterium	2%	2%	3%	3%	4%	7%
Carbon	3%	3%	3%	4%	5%	9%
Copper	4%	4%	4%	5%	7%	11%

Table 1 : statistical errors expected for l_c = 0.4 fm and different bins in Q^2, E_e = 6 GeV.

Target \ Q^2 (GeV^2)	1.25 ± 0.25	1.75 ± 0.25	2.25 ± 0.25	2.75 ± 0.25	3.25 ± 0.25
Deuterium	2%	2%	2%	5%	10%
Carbon	2%	2%	3%	5%	11%
Copper	2%	2%	3%	8%	13%

Table 2 : statistical errors expected for l_c = 0.5 fm and different bins in Q^2, E_e = 6 GeV.

Target \ Q^2 (GeV^2)	0.75 ± 0.25	1.25 ± 0.25	1.75 ± 0.25
Deuterium	3%	3%	5%
Carbon	3%	3%	6%
Copper	4%	4%	6%

Table 3 : statistical errors expected for l_c = 0.5 fm and different bins in Q^2, E_e = 4 GeV.

From the estimated count rates, the statistical error on the nuclear transparency T_A varies from 2% (low Q^2) to 9% (high Q^2) for carbon and from 2% to 11% for copper, see Tables 1-3. Sources of systematic errors will be discussed in the next section. For the photoproduction measurements, we expect to obtain 3% statiscal precision with 1 day data taking for each target. The l_c value for these measurements would be 1.2 fm. We expect to obtain the same l_c value from 4 GeV electron data at Q^2 = 0.75 GeV^2. The predicted variation of the nuclear transparency from Q^2 = 0 to Q^2 = 0.75 GeV^2 makes the photoproduction measurements worthwhile. The Q^2 = 0 point can be useful in the control of different systematics such as the radiative corrections. We should also keep in mind that the photoproduction measurements correspond to the value one would obtain if no CT effects appear. The projected measurements at the proposed values of l_c are presented in Figure 6. Curves are the expectations of Ref. [20]. They show a CT effect on the value of T_A at $Q^2 \sim 4$ GeV^2 of 35% for carbon and 65% for copper, meanwhile Glauber calculations predict no Q^2 dependence of the nuclear transparency. We must recall that data with all possible values of l_c, Q^2 and t' will be taken at the same time and will certainly be used. A common fit to all available data at fixed l_c with the slope of Q^2 as a free parameter will be performed. One can use $T_A = a + b \cdot l_c + c \cdot Q^2$ form with a, b and c as free parameter. This fit procedure will allow the determination of the Q^2 dependence (parameter c) with greater precision. Using only l_c values of 0.4, 0.5 and 1.2 fm, we can obtain 4σ precision on the Q^2 slope parameter c for carbon and 5σ for copper. The measurements at Q^2 = 0 will put more constraint on the value of the parameter a.

All estimates in this proposal consider the CLAS detector without any modifications to the standard configuration and under standard running conditions. The measurements may be improved by reversing the torus field for the 4 GeV beam period, thus obtaining a point at even lower Q^2. However, previous runs with reverse field in CLAS have shown that the efficiency of the Cherencov counter for out-bending electrons at small scattering angles is difficult to predict, thus making it difficult to properly normalize such data. An effort will be made to further investigate reverse field running and the possibility to obtain proper particle identification without relying on the Cherencov counter.

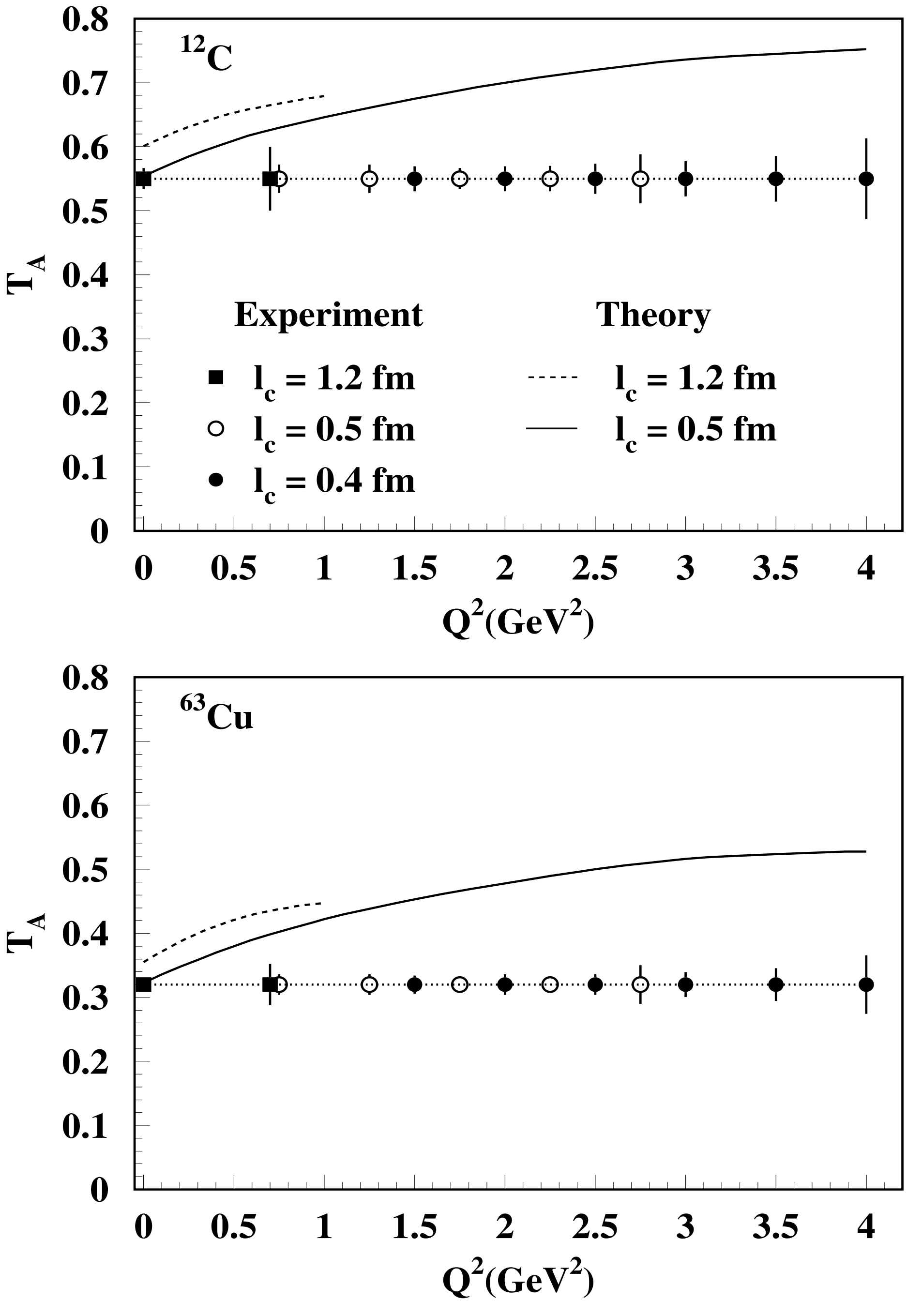

Figure 6: Expected error bars for the proposed measurements and predictions of [20].

It would also be possible to increase the acceptance of small scattering angle electrons, as well as the π^-, by moving the target upstream by about 50 cm. Such a configuration requires a new solenoidal magnet to shield the region 1 chambers from Moller electrons. Since it is not clear when this new equipment will become available, and considering that, we will only gain one more Q^2 point at 0.6 GeV^2 from this configuration, this proposal plans for the target at the center of CLAS.

4 Systematic uncertainties

In this section, various sources of systematic uncertainties will be discussed. These sources include the absorption of the decay pions inside the nucleus, the background subtraction and the radiative corrections.

4.1 Pion absorption

To consider the absorption of ρ^0 decay pions inside the nucleus, we have used the intranuclear cascade model ISABEL [24]. ISABEL uses experimental nucleon-nucleon and π-nucleon cross sections and angular distributions and can simulate N-A and π-A interactions. First, using the decay length of produced ρ^0 particles, we have determined the proportion of events where the ρ^0 decays inside the nucleus. Then, for these events, each of the decay pions is sent as projectile on the nucleus where it generates an intranuclear cascade. The proportion of absorbed ρ^0 decreases with Q^2 because higher Q^2 corresponds to more energetic decay pions to which the nucleus is more transparent. For example, at low Q^2 ,10% of the decay pions against only 2% at high Q^2 are absorbed on carbon. The following table summarizes the result of these calculations for both carbon and copper.

Target	ρ^0 decay inside	$\pi^+\pi^-$absorbed	Error
Carbon	10-30 %	2-10%	1-3%
Copper	20-50%	4-16%	2-5%

Table 4 : Nuclear absorption effect and the corresponding errors.

Lower limits in this table correspond to high Q^2 and upper limits to low Q^2. Errors are estimated assuming a 30% error on the result of ISABEL. The same code was used to study the influence of the nuclear medium on the reconstructed $\pi^+\pi^-$ invariant mass. As one can see from Fig.7, the effect of the pions energy and angular straggling in the nuclear medium does not affect the shape of the reconstructed ρ^0 mass.

4.2 Background Contributions

Analysis of existing CLAS electroproduction data off the carbon at a 4.45 GeV electron beam showed that incoherent diffractive ρ^0 electroproduction process can be reliably identified. The invariant mass of the detected $\pi^+\pi^-$ presented in figure 8 shows the typical ρ^0 mass distribution.

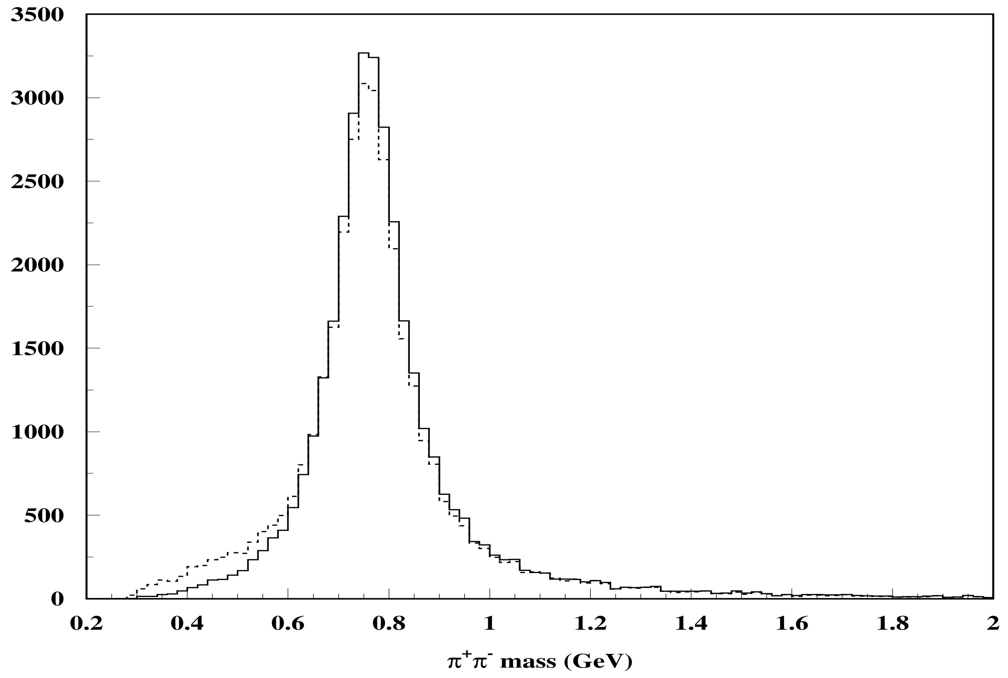

Figure 7: The solid curve is the initial reconstructed invariant mass of the ρ^0 decay pions. The dashed curve is their reconstruted mass after they left the copper target.

Due to the fact that the ρ^0 meson is a quite large resonance, the main issue one has to deal with is the background subtraction. Many processes can contribute to this background. The main channels that can produce a $\pi^+\pi^-$ pair in the final state and could contribute to the background are :

- $\gamma^* p \rightarrow p\omega(\pi^+\pi^-\pi^0 : 88.8\%, \pi^+\pi^- : 2.2\%)$
- $\gamma^* p \rightarrow p\phi(K^+K^- : 49.1\%, \rho\pi + \pi^+\pi^-\pi^0 : 15.5\%)$
- $\gamma^* p \rightarrow pf_2(1270)(\pi^+\pi^- : 84.7\%, \pi^+\pi^-2\pi^0 : 7.1\%, 2\pi^+2\pi^- : 2.8\%)$
- $\gamma^* p \rightarrow p\Delta^{++}\pi^0 \rightarrow p\pi^+\pi^-$
- $\gamma^* p \rightarrow p\Delta^0\pi^+ \rightarrow p\pi^-\pi^+$

A non detected π^0 in the 3π decay of ω is one of the sources of contamination to the ρ^0 peak. We expect the corresponding $M_{\pi^+\pi^-}$ spectrum to be centered about 0.45 GeV with a width of 0.075 GeV (using Dalitz plot for $\omega \rightarrow 3\pi$). This means that the majority of these events is outside the relevant ρ^0 invariant mass window. We estimated the residual contamination to be about 2 %. The contribution of the $\pi^+\pi^-$ pairs of the $\omega(782)$ resonance to the ρ signal is expected to be small due to its 2% decay branch to $\pi^+\pi^-$. Considering the higher mass of the resonance f_2, we expect that most of them will be eliminated by cutting on ΔE, but due to its large width a residual contribution could mix-up with the high mass tail of the ρ^0. A recent Hall B collaboration analysis [30] showed that f_2 becomes more important at high $|t'|$, cutting on $|t'| < 0.5$ GeV will reduce this contribution to less than 1 %. For the other sources of background, the CLAS collaboration has already published data on ρ^0 photoproduction off the proton [31]. This paper shows that the systematic uncertainties related to the background subtraction is about 5% in our t' region. Despite this, one could expected that in the case of nuclear targets, the quoted systematic error can be higher. We believe that this error on the nuclear ratio could be kept at the 5% level as shown by HERMES analysis.

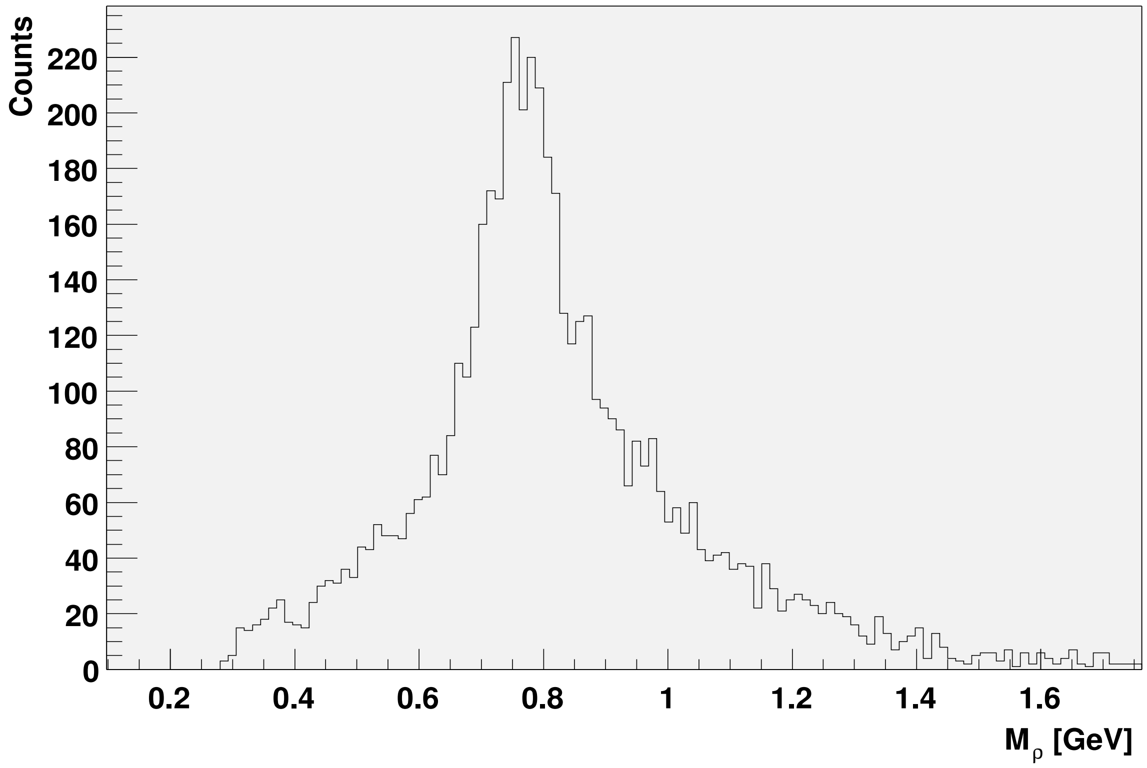

Figure 8: Reconstructed invariant mass of the ρ^0 decay pions using CLAS data of 4 GeV electron beam on carbon.

4.3 Radiative Corrections

The radiative corrections to the ρ^0 production cross section are estimated using the code DIFFRAD [32] written for exclusive vector meson production. In addition to the radiation of real photons, this code includes "virtual" corrections like vacuum polarization and vertex corrections. The mean values of the kinematical variables Q^2, W^2 and t, calculated using our Monte-Carlo model for the considered (lc, Q^2) bins, are used as input to the numerical version of the code. The correction to the cross section is found to vary from 5 to 15 %. The correction to the nuclear transparency, which is the ratio of the cross section on a nuclear target to the one measured on a nucleon, is 1-5%. Considering the cross section model dependence of the correction, we expect the corresponding systematic error to be less than 2%.

5 Beam request

Measurements of the nuclear transparency for carbon and copper at 6 and 4 GeV electron beam have been proposed. The process in question is diffractive incoherent ρ^0 electroproduction. The same measurements have also been proposed for photon beam of about 2 GeV.

The total beam time requested for these measurements is 1152 hours (48 days). 720 hours with a 6 GeV electron beam, 360 hours with 4 GeV electrom beam and 72 hours with 1.7-2.2 GeV photon beam. This time is for data taking only and does not include calibration time. The efficiency of both the accelerator and CLAS are assumed to be 100%.

Target \ Q^2 (GeV^2)	photon beam	4 GeV electron beam	6 GeV electron beam
Deuterium	24h	120h	240h
Carbon	24h	120h	240h
Copper	24h	120H	240h

Table 5 : Photon and electron beam time requested on each target.

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