THE EXTRACTION OF THE INVARIANT MASS SPECTRUM FROM THE ELECTRON-DEUTERON SCATTERING BY INCLUSIVE ANALYSIS OF THE BLAST DATA

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Abstract

Data from scattering polarized electrons, linearly accelerated up to 850 MeV energy, off polarized hydrogen and deuterium targets have been collected with BLAST Spectrometer at Bates Laboratory of Massachusetts Institute of Technology (MIT) between 2003 and 2005. Among these data, the analysis of the electron-deuteron scattering part of the data for the measurement of the double spin asymmetry via pion photo-electro production technique has begun recently. Here, we present four momentum transfer square (Q^2) and the invariant mass (W) spectra, and its dependence to Q^2 as the initial results of the analysis. It was seen that the results satisfied the theoretical expectations. In addition, due to the necessity that the later analysis will be done in the resonance region, it was understood that the condition of W of the scattering being above 1.1 GeV/c^2 has to be met for the isolation of the region from the non resonant one.

Key Words: Invariant mass, polarized target, electron-deuteron scattering, squared 4-momentum transfer, electromagnetic interaction.

Özet

850 MeV enerjisine kadar doğrusal olarak hızlandırılan polarize elektronların polarize hidrojen ve polarize döterondan saçılmasından oluşan veri 2003 ile 2005 yılları arasında Massachusetts Yüksek Teknoloji Enstitüsünün (M.I.T.) Bates Laboratuvarında BLAST Spektrometresi kullanılarak toplanmıştır. Bu verilerden elektron-döteron saçılma verisinin piyon elektro-foto üretim tekniği ile çifte spin asimetrisinin ölçümü için analizine başlanmıştır. Bu çalışmada analizin ilk sonuçları olan dört momentum transfer karesi (Q^2) ve değişmez külte (W) spektrumlarını ve W'nun Q^2 'ye bağlılığını sunmaktayız. Sonuçların kuramsal beklentilerle uyumlu olduğu tespit edilmiştir. Özellikle

sonraki analizlerin rezonans bölgesinde yapılması gerekliliğinden dolayı bu bölgenin elastik bölgeden ayrılması için bu tür saçılmalar için W'nun 1.1 GeV/c^2 değerinin üzerinde olması şartının aranması gerektiği anlaşılmıştır.

Anahtar Kelimeler: Değişmez kütle, polarize hedef, elektron-döteron saçılması, dört momentum transfer karesi, elektromanyetik etkileşim.

1. Introduction

The technique of probing the structure of composite particles such as atoms, nuclei or hadrons etc. remains basically the same since Rutherford's experiments regarding the understanding of the atomic structure known as scattering [1]. Typically, it is mainly to shoot a point particle with a speed high enough such that its de Broglie wave will be smaller than the size of the composite particle to be studied [2]. Tracking the outgoing particles carries clues regarding the target particle's internal structure. With the recent technological developments on the ability to polarize both incident and target particles additional knowledge has been possible [3]. Using a parallel but not the same technique a series of experiments were conducted at Bates Laboratory of M.I.T. between 2003 and 2005. The facility typically delivered ~ 70% polarized electrons with energies up to 1 GeV with currents of ~ 175 mA and lifetimes of ~ 25 min. The longitudinal polarization of the beam was maintained by a Siberian Snake and was monitored by a Compton polarimeter [4]. The toroidal magnetic field was produced by eight coils and achieved a maximum of ~ 3800 G in the drift region. The BLAST (Bates Large Acceptance Spectrometer Toroid) detector system covered 20-80 degrees in polar angle and ± 15 degrees in azimuthal angle both left and right of the beamline. Time of flight (TOF) scintillators, Čerenkov detectors, wire chambers, and neutron counters are the main components of the detector and were used for relative timing, particle identification, charged particle tracking, and neutron detection, respectively (Fig. 1).

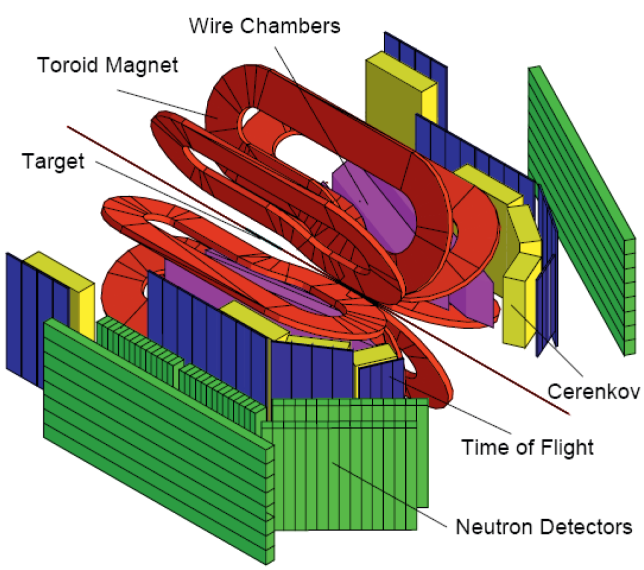

Figure 1 An isometric view of the BLAST detector showing the main detector elements

The polarized electron beam was produced by exposing GaAs, a semiconductor material, to a circularly polarized laser beam [5-6]. On the other hand, highly polarized protons and deuterons were generated through Atomic Beam Source (ABS) that turns the molecular form of gases into the atomic form first and populates selectively the desired polarization states afterwards [7].

2. Analysis

In this study, the type of analysis performed is inclusive, and therefore, only scattered electrons are detected throughout the process. Data used in the analysis consists of 10 runs chained. Each run is about an hour long, and includes ~100K events. In BLAST data acquisition system, 8 trigger types are used to collect multi reaction channels simultaneously [8]. In this analysis all events are included regardless of the trigger type. The details for the identification of the scattered electrons at BLAST are given below.

2.1 Particle Identification

The type of charged particles detected in one sector of the Blast system were tagged with a number, called particle identification (PID) number and were recorded in the crunched data for every detected events (Fig. 2). This will enable one to distinguish particles belong to a particle type from others. If the PID number corresponding to a particle type is not known, then one can identify it by applying a cut consists of the charge info stored in units of e with the mass stored in units of GeV/c^2 of the particle with logical "and" statement in the cut to be applied to data. Such a cut for electrons gives 3 as the PID number (Fig. 3) info.

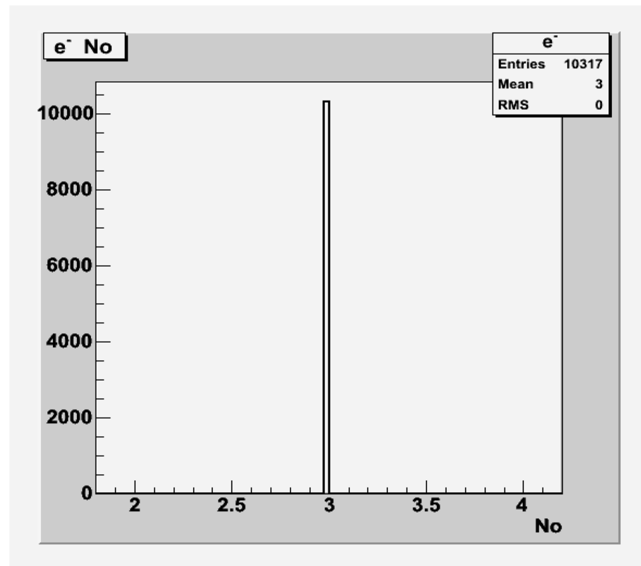

Figure 2 Event distribution relative to the particle types depending on the PID number.

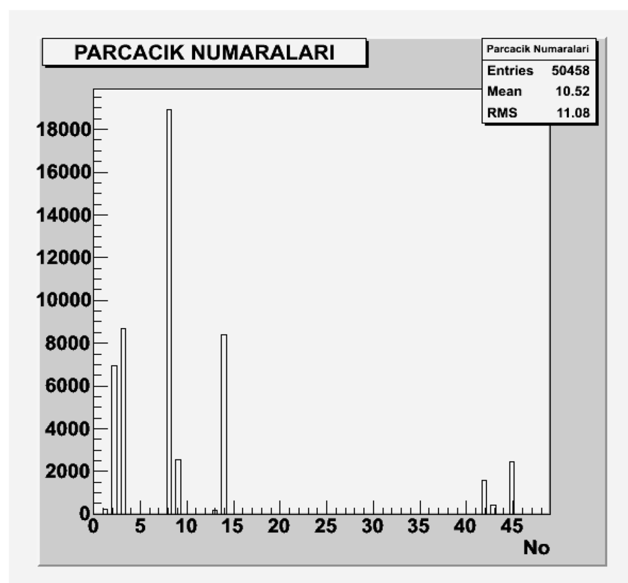

Figure 3 Same as Fig. 2 but with the charge and mass cut applied to select electrons.

2.2 Acceptance Cut

Since the inclusive analysis was based on detecting just the scattered electrons, all the reaction channels would be included in the analysis. For this reason, on top of PID cut applied to data, a number of additional cuts were necessary to minimize the misidentification of any electron to be a scattered one. One of these cuts was to impose the polar (θ) and the azimuth (Φ) angle coverage of the BLAST, mentioned earlier, in order to reject any electrons coming outside that region.

2.3 Vertex and Momentum Cuts

Another cut was applied to make sure that the electron was coming to the target region. The target is 60cm long hollow tube located at the center of the spectrometer and positioned parallel to the beam line, or z axis. To determine if the electron is coming from the target region of which z is between -30 cm and 30 cm, one needs to know the vertex position for the scattering event. This is obtained by tracing the electron's trajectory through the mapped magnetic field back to the target region [9]. The vertex position distributions for the electrons are shown in Fig. 4 and in Fig. 5.

Another cut is to reject electrons with the low momentum, below 0.25 GeV/c. Such threshold is applied to prevent background electrons from being considered as the scattered electrons in the process of analysis [9].

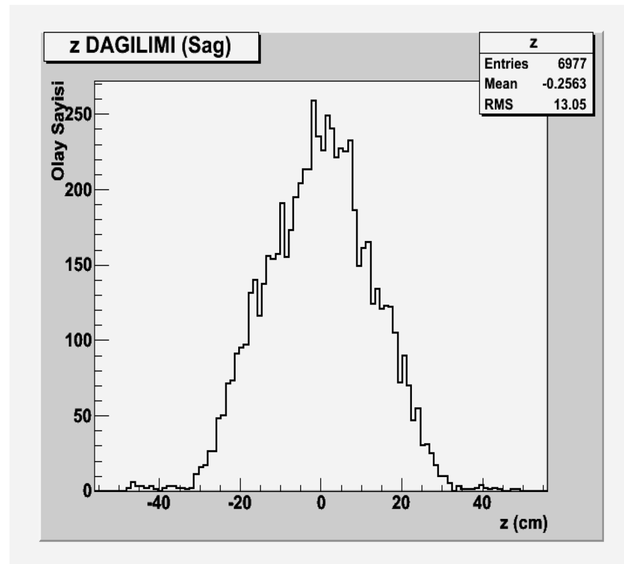

Figure 4 Vertex distribution for the electrons detected on the left sector.

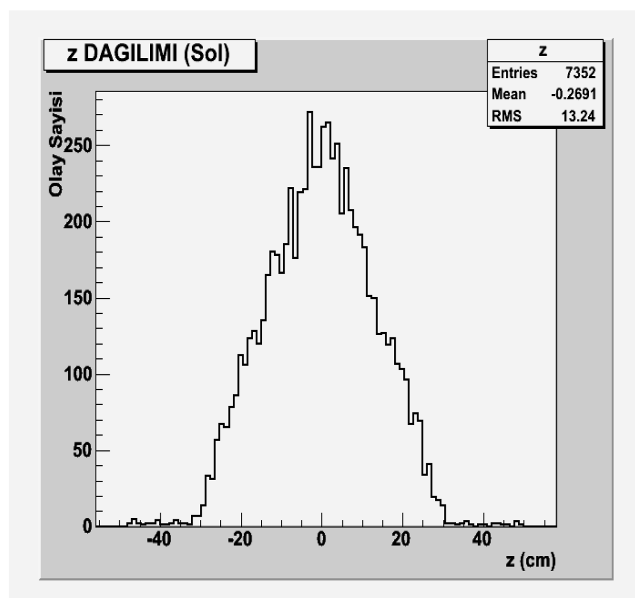

Figure 5 Vertex distribution for the electrons detected on the right sector.

3. Results and Discussion

Once the electron identification is made with the cuts above as accurate as possible, some kinematical quantities can be accessed. Below Q^2, W, and the Q^2 dependence of W for the BLAST data are considered.

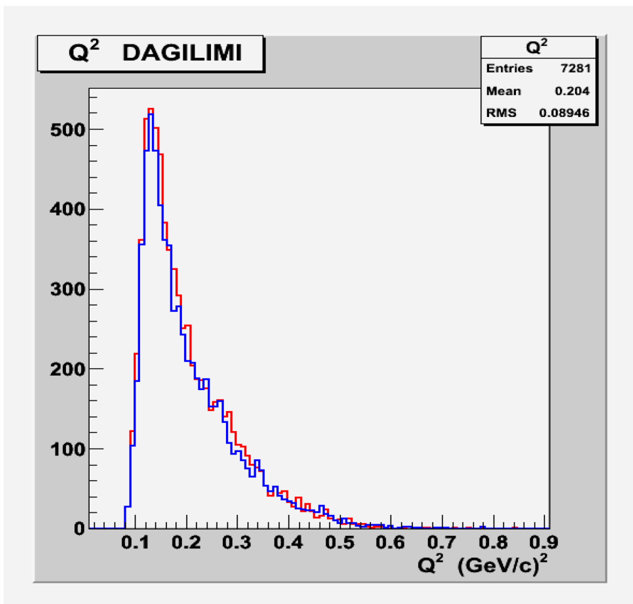

Figure 6 Q^2 distributions of the BLAST Experiment for left (blue) and right (red) sectors

3.1. Q^2 Spectra

After the determination of the scattered electrons with the cuts mentioned above, the distribution of the four vector momentum transferred square Q^2 can be obtained (Fig. 6) [10]. From the figure, Q^2 range for the BLAST can be found to be between 0.1 – 0.5 $(GeV/c)^2$. The observation of quite the same distributions for both sectors is evident, and can be a measure for the validity of the analysis.

3.2. W Spectra

Beside Q^2, another quantity whose distribution or spectrum can be extracted is the invariant mass (W) of γN system, where γ and N are the virtual photon emitted from the incident electron during the electromagnetic interaction process and one of the deuteron's nucleon, respectively (Fig. 7) [10]. It is a quantity that remains invariant under the Lorentz transformations. The W spectrum of the system is shown in Fig. 8 [10].

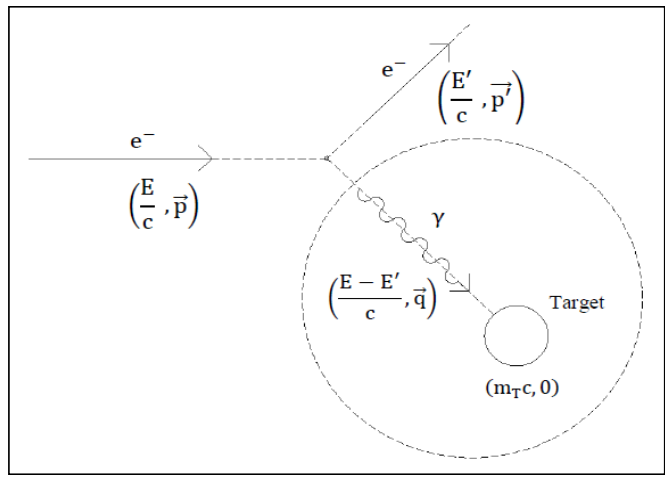

Figure 7 A schematic drawing of e-d scattering through electromagnetic interaction in the lab frame. The circle with the dashed line is used to emphasize particularly on the system formed by the virtual photon γ and one of deuteron's nucleon N as the target.

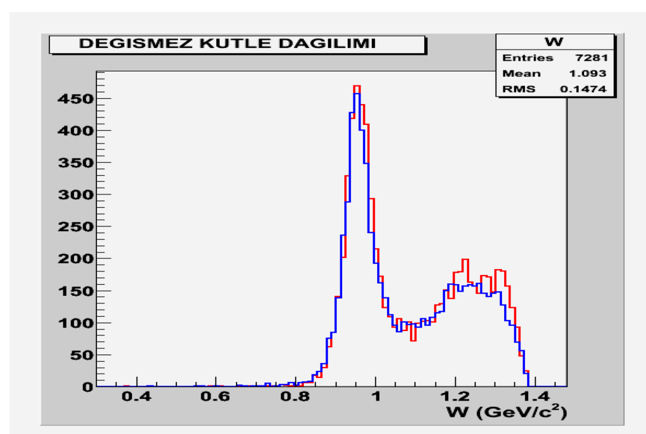

Figure 8 W spectra of the BLAST Experiment for left (blue) and right (red) sectors

In the spectrum, two peaks are evidently seen within the W range of the experimental data. First one, being narrow and tall, has a maximum at the point very close to the nucleon mass (~0.94 GeV/c^2) due to the elastic part of the scattering, while the second one, being wide and short, has a maximum at the point very close to the mass of the delta (1.23 GeV/c^2), the first resonance state of the nucleon. The W spectra obtained from left and right sectors are quite similar in shape and size. Moreover, it can be seen that the upper range of W for the BLAST be ~1.4 GeV/c^2.

3.3. Q^2 Dependence of W

The Q^2 dependence of W can be studied by looking W spectra for sub ranges of the Q^2 (Fig. 9) [10]. The last plot in the figure (bottom-right) has less statistics to deduce any conclusion. However, from the first three plots one can see that the ratio of the heights of the nucleon peak to that of the Δ peak changes noticeably from ~3 at the first plot where the sub range starts at the lowest Q^2 value of 0.1 (GeV/c)^2, to ~1 at the third plot where the sub range ends at the highest value of 0.4 (GeV/c)^2. This may imply that the number of elastic reactions diminishes and that of the inelastic reactions becomes more pronounced at higher Q^2 region.

4. Conclusion

With this work, we have started to work on the analysis of deuteron scattering data taken with BLAST spectrometer. As the beginning, Q^2 and W spectra were extracted, and the Q^2 dependence of W is checked by looking the W distributions for sub ranges of Q^2. The Q^2 range and W top range were found to be between 0.1-0.5 (GeV/c)^2 and 1.4 GeV/c^{2}for the BLAST, respectively. Within this W range the expected two peaks, elastic one very close to nucleon mass and the inelastic one very close to delta mass, were observed. The behavior of the Q^2 dependence of W was put forward. Finally, it can be said that all the results be consistent with the physical expectations, and that this consistency, in turn provides the necessary motivation for analyses to come.

5. Acknowledgements

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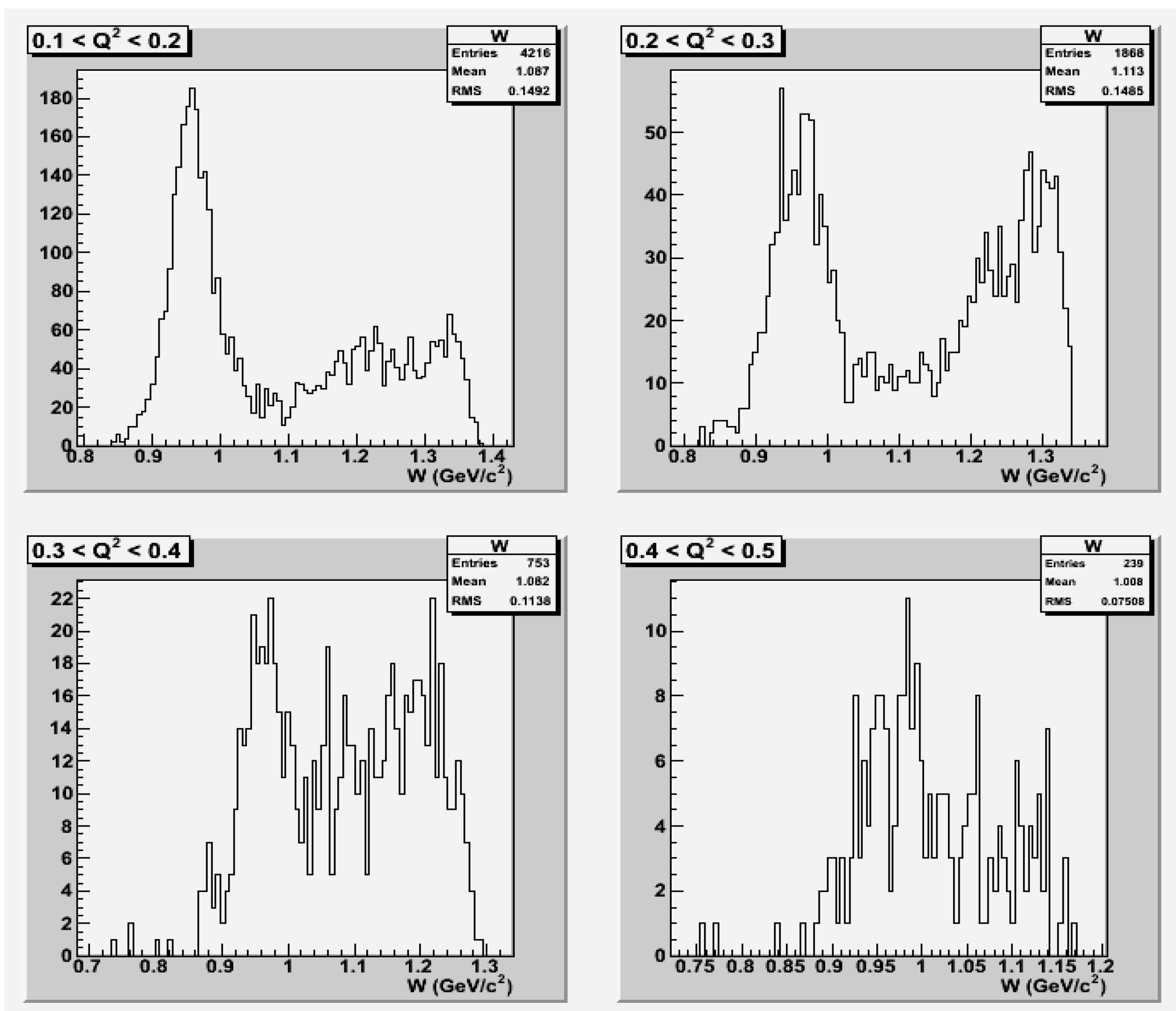

Figure 9 W spectra for Q^2 sub ranges in 0.1 GeV^2/c^2 increments from the lowest to the highest Q^2.