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Physics

THE RADIATIVE CORRECTIONS ACCOUNTING IN THE REACTION NEAR-THRESHOLD OF J/ψ MESON PHOTOPRODUCTION

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The use of the method developed in the CLAS collaboration (Jefferson Lab, USA) of improving leptons momentum for more correct studies of final state selection of quasi-real photoproduction resulting from the reaction to near threshold photoproduction of the J/ψ meson is described. The radiation photons that were detected in electromagnetic calorimeter were studied with electrons and positrons accompanied them in very narrow angles. The method of radiated photon selection of $e^+e^-p'(e')$ reaction is given, where e^+e^- lepton pair is formed during the decay of J/ψ meson.

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***Keywords*:** radiated photon, momentum correction, J/ψ meson.

Introduction.

The Near-Threshold J/ψ photoproduction. An attempt to understand the structure of a nucleon in terms of quark and gluon degrees of freedom is one of the currently important topics of modern nuclear physics. An important role in achieving this goal is played by the study of the interaction of heavy quarkonia with the hadronic matter. The smallness of the spatial size of heavy quarkonia, on the hadron scale $r_{Q\overline{Q}} < 1$ fm, allows one to describe their interaction with hadrons to use, in an admissible approximation, the operator methods of quantum chromodynamics (QCD) [1–3]. For J/ψ extraction analysis requires accurate identification of electrons, positrons, and protons.

The CLAS12 particle identification system consists of three components: identification of electrons, identification of charged hadrons $(p, \pi^{\pm}, K^{\pm\cdot})$ and identification of neutral particles (n, γ). Electrons and photons are registered and identified in FD and charged hadrons and neutrons in both Forward Detector and Central Detector. For the analysis, data are used that have been pre-processed and recorded following the standard software adopted in hall B. At the stage of data processing, all recovered particles are assigned initial identifiers (PIDs). The notation for identifiers is the

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same as in the PDG (Particle Data Group). This identifier assignment is based on a combination of signals from different components of the CLAS12.

Event selection. The first step in isolating the events of interest for the reaction $e^-\gamma \to e^+e^-p$, was the selection of particles of the final state, for which the events with one proton, one electron, and one positron were selected from the entire data set. The next step was to refine the particle identifiers assigned at the stage of primary processing, for which certain restrictions were imposed both on the kinematic characteristics of the particles under study and the geometric regions of the detector. Particle detection efficiency in CLAS12 depends on the kinematic parameters of the particles (momentum, azimuth, and polar angles). After identification of the particles, a 3-dimensional region (p, θ, ϕ) was determined, in which the efficiency of particle detection is almost constant, and only those events were selected in which all particles (e^+e^-p') fell into this region.

Method implementation. After this initial selection of events, the so-called "exclusivity cuts" were applied, namely, restrictions on the kinematic characteristics of the missing particle in the reaction $e^-p \to e^+e^-p'X$. According to the technique used, the mass and magnitude of the transverse component of the momentum of the missing particle should be small.

For the final selection of reaction events $e^-p \to e^+e^-p'e'$, the following restrictions were applied: $|P_{tr}/P_{miss}| < 0.05$, $|M^2_{miss}| < 0.4\ (GeV/s^2)^2$ corresponds to the quasi-real photoproduction of an e^+e^- pair, because the virtuality of the intermediate photon is very small: $Q^2 < 0.02\ (GeV/s^2)^2$. After invariant mass of e^+e^- pair was made (Fig. 5, right) [4].

CLAS12 Device and Experiment. Located in Experimental Hall B of Jefferson laboratory, the CLAS12 magnetic spectrometer [5] is designed based on the CEBAF (Continuous Electron Beam Accelerator Facility) Large Acceptance Spectrometer (CLAS) in connection with the 12 *GeV* reconstruction of the CEBAF accelerator. This is a complex installation designed for a wide range of experiments to study the structure and interaction of nucleons, nuclei, and mesons, using polarized and unpolarized electron beams and targets, for beams with energies up to 11 *GeV*. The CLAS12 is based on a dual magnet system consisting of a superconducting toroidal magnet providing mainly azimuthal field distribution with a polar angle range of up to 35 *deg* in the front of the unit, as well as a solenoidal magnet and detector covering polar angles from 35 *deg* to 125 *deg* full azimuth coverage. The detector is functionally divided into two parts: the front part, FD (Forward Detector), and the central part, CD (Central Detector). The reconstruction of the trajectory in the forward direction, using drift chambers, and in the central part, using the vertex detector, gives a momentum resolution of $< 1\%$ and $< 3\%$, respectively. The Cherenkov counters, time-of-flight scintillators, and electromagnetic calorimeters (EC) provide good particle identification. Fast start-up system and high data acquisition rate allow operation at the luminosity of $10^{35} cm^{-2}s^{-1}$.

The studies were carried out according to the data of experiment E12-12-001 [6], conducted in Hall B, Jefferson's laboratory. In the experiment, a 10.6 *GeV* electron beam with a luminosity of $0.7 \cdot 10^{35} cm^{-2} s^{-1}$ was scattered by a liquid hydrogen target installed in the center of the CLAS12 spectrometer.

The subject of research is the reaction of unmarked quasi-real photoproduction, $\gamma p \to J/\psi p(l^+)l^-$, where $(l^+)l^-$ is a lepton pair from the decay of the J/ψ meson. The events of a completely exclusive electroproduction were selected:

$$e^- p \to e^+ e^- p'(e'). \tag{1}$$

Here (e') denotes an undetectable scattered electron whose kinematics are reconstructed based on the analysis of the missing momentum. The other three particles, the recoil proton, p' and the resulting pair of leptons, e^+e^-p', are registered in the front of the CLAS12 device.

Electron-positron Radiation. Radiated photons accompanying the scattered electrons and positron can be observed in CLAS12. At the point of radiation, the photon has the same angles as the electron. These radiations can be identified by analyzing the differences of the angles of the electrons, positrons and the neutral hits. In the longitudinal field of the solenoid, at the point of the radiation, the polar angle of the electron is the same as at the production vertex. The azimuthal angular difference is more complicated. It is influenced by many factors, such as the solenoid field, the electron, positron momentum and the location of the radiation points.

$$\theta_\gamma \approx \theta^r_{e^\pm} \approx \theta^v_{e^\pm}, \qquad \phi_\gamma \approx \phi^r_{e^\pm} \neq \phi^v_{e^\pm}. \tag{2}$$

Calculations that involve the momenta of the electron-positron pair, such as the invariant mass, can be sensitive to the effects of radiative energy loss by the electrons and positrons. As the electrons move from the vertex to the Forward Detector (FD), energy can be lost from radiation at the vertex in the target, in the scattering chamber, on the materials of the Silicon Vertex Tracker (SVT) closure, High Threshold Cherenkov Counter (HTCC) windows, and mirrors – essentially any material that precedes the drift chambers. The part of radiated photons will be detected in the Electromagnetic calorimeter (ECAL) and the ones that have been radiated before the lepton reaches the drift chambers can be easily idented.

The measured energy of the radiated photons can be used to reconstruct the momentum of leptons at the production vertex. It is important to note this effect into account so that events can be stored for correct reductions in exclusivity and correct measurements of invariant mass.

Identification of Radiated Photons. At the point of radiation, the photon has the same angles as the electron or positron. These radiations can be identified by analyzing the differences of the angles of the leptons and the neutral hits. Radiated photons in ECAL can be identified by analyzing the differences of reconstructed angles of the electron and that of a neutral hit, which were detected in the same sector [4, 7]:

$$\Delta\theta = \theta_\gamma - \theta^r_e \quad \Delta\phi = \phi_\gamma - \phi^r_e. \tag{3}$$

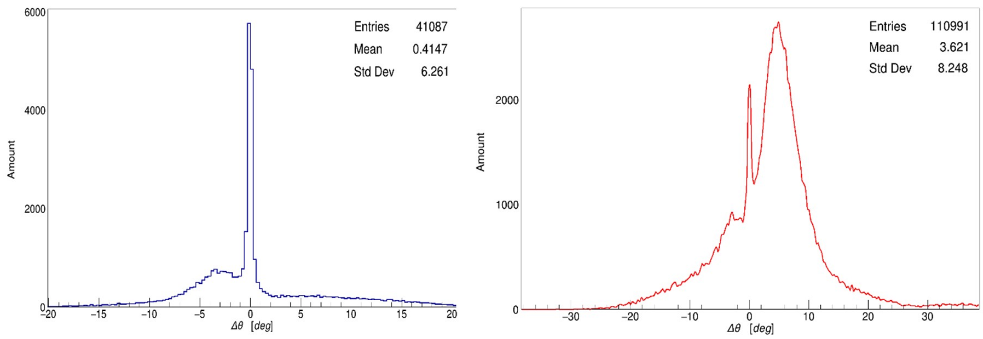

Fig. 1. Distribution $\Delta\theta$ of reconstructed electron-photon(left) and position-photon (right) pairs.

The 1-dimensional distributions obtained from data are plotted in Fig. 1. A narrow peak can be observed at $\Delta\theta = 0$. These are the radiated electron-photon and positron-photon pairs. From this point the radiated photons will be defined with a cut on $|\Delta\theta| < 0.8°$. After selecting the angular range radiation photons number and momentum was studied. Radiated photon tagging can also be used to study the efficiency of particle identification. Neutral and charged particles that have the same θ angles are misidentified radiated photons.

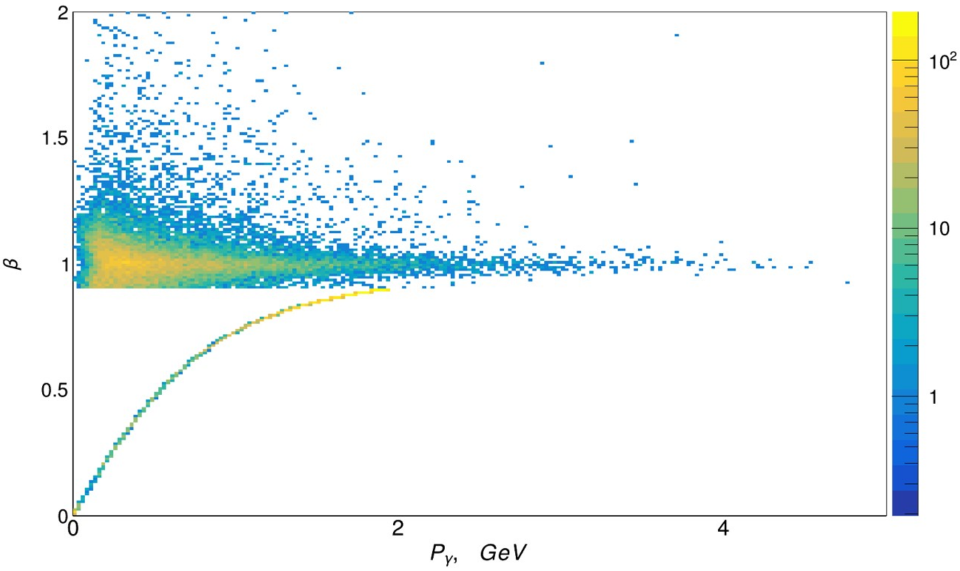

Fig. 2. Distribution of the dependence of the velocity β on the momentum for any neutral particle that has passed the $|\Delta\theta| < 0.8°$ cut.

As it is shown on Fig. 2, a, large portion of the radiated photons are reconstructed as neutrons due to the strict $\beta > 0.9$ cut. These misidentified photons were used throughout the analysis with recalculated 4-momenta. The recalculated energy is:

$$E = \frac{E_{tot,\,dep}}{sampling\ fraction},$$

where

$$sampling\ fraction = 0.25(1.029 - 0.015/E_{tot} + 0.00012/E_{tot}^2)$$

and E_{tot} is a total energy detected in ECAL.

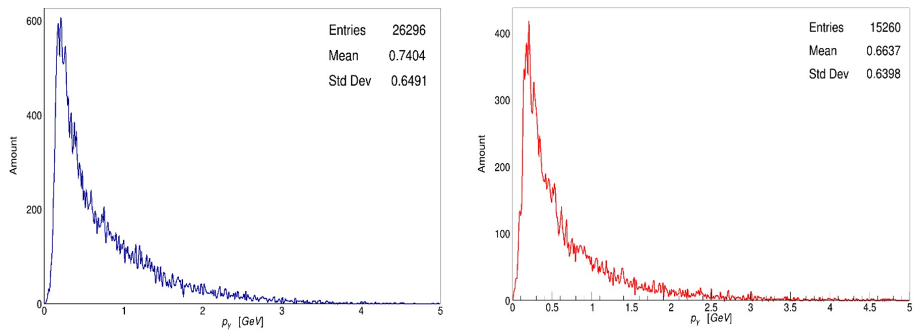

Fig. 3. Energy distribution of the electron's radiated photons (right) and positron's radiated photons (left).

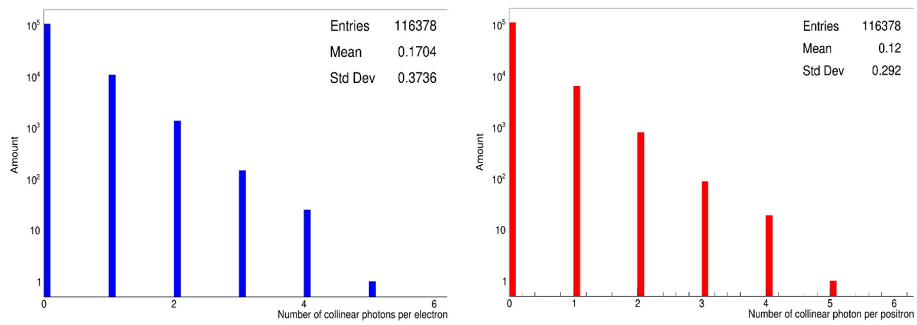

Fig. 4. Number of radiated photons per electron (right) and per positrons (left).

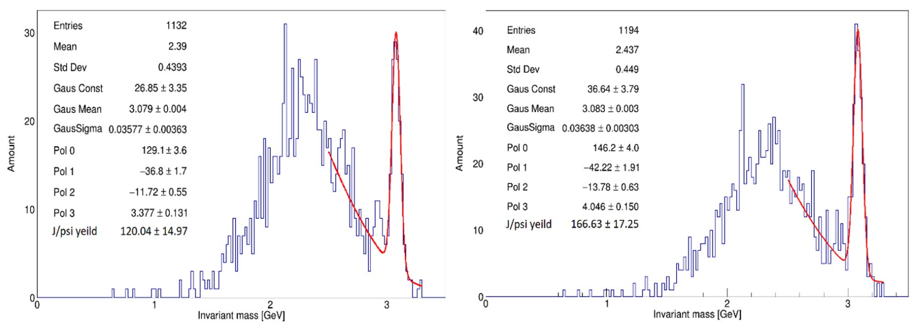

Fig. 5. Invariant mass distribution before (left) and after (right) radiation correction.

The energy distribution (Fig. 3) and the number of radiated photons (Fig. 4) are well reconstructed from data. 10.55% of the detected electrons and 6.11% of the detected positrons radiated. Over 95% of the radiated events 1 or 2 photons were radiated. And as it can be seen major part of electrons and positrons do not have radiated photons. The effect of correction shown is Fig. 5. Were presented invariant mass before and after correction.

Conclusions. In the article the method of accounting for the radiation losses of an electron / positron in the near-threshold of J/ψ photoproduction reaction is described. After radiated photon correction, particles momentum and energy got increase. This also has affected on the reconstruction of miss-identified photons. Which as a total influence to the exclusivity cuts such as missing mass and Q2. The effect of correction can be seen on Fig. 5. Were presented invariant mass before and after correction. According to the statistic the yield of J/ψ resonance increase up to 39%.

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Դ. Ա. ՄԱՐՏԻՐՅԱՆ

ՌԱԴԻԱՑԻՈՆ ՈՒՂՂՈՒՄՆԵՐԻ ՀԱՇՎԱՌՈՒՄԸ ՇԵՄԻՆ ՄՈՏ J/ψ ՄԵԶՈՆԻ ՖՈՏՈԾՆՄԱՆ ՌԵԱԿՑԻԱՅԻՑ

Աշխատանում ներկայացված է, CLAS (JeffersonLab, ԱՄՆ) համագործակցության հետ մշակված, վերջնական վիճակում գնվող քվազիիրական ֆոտոծնման շեմին մոտ J/ψ մեզոնի ֆոտոծնման ռեակցիայի արդյունքից առաջացած լեպտոնների իմպուլսի բարելավման, ավելի հստակ ընտրության մեթոդը կիրառումը: Էլեկտրամագնիսական կալորիմետրում գրանցված ճառագայթային ֆոտոնները ուսումնասիրվել են նրանց ուղեկցող էլեկտրոննեիր և պոզիտրոնների հետ նեղ անկյունային տիրույթում: Բերված է $e^+e^-p'(e')$ ռեակցիայից ճառագայթային ֆոտոնների ընտրության մեթոդը, որտեղ e^+e^- լեպտոնային զույգը առաջացել է J/ψ մեզոնի տրոհումից:

Д. А. МАРТИРЯН

УЧЕТ РАДИАЦИОННЫХ ПОПРАВОК В РЕАКЦИИ ОКОЛОПОРОГОВОГО ФОТОРОЖДЕНИЯ J/ψ-МЕЗОНА

В работе описано использование разработанного в коллаборации CLAS (JeffersonLab, США) метода по улучшению импульса лептонов для более корректного исследования селекции конечного состояния квазиреального фоторождения в результате реакции на околопороговом фоторождении J/ψ-мезона. Фотоны излучения, зарегистрированные в электромагнитном калориметре, изучались с электронами и позитронами, сопровождающими их в очень узких углах. Приведен метод селекции излучаемых фотонов в реакции $e^+e^-p'(e')$, где e^+e^- – лептонная пара, которая образуется при распаде J/ψ-мезона.