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Identification of Coherent ($\pi^+\pi^-$) Pairs Production in High Energy Photon-Deuteron Scattering

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Introduction. Coherent scattering reactions on nuclei often is used to study dynamics of production and rescattering of meson resonances off the nucleons inside nuclei. A particular case of such process is the coherent photoproduction of vector mesons on deuterium. Because of the large photon-vector meson coupling the cross section of such process is large, and at high energies and low momentum transfer is well understood in the framework of the vector meson dominance (VMD) model [1]. The deuteron is the best understood nucleus, and the distance scales (coherence length and formation length) reachable at JLAB are comparable to the inter-nucleon distance in the deuteron. Coherent production of vector mesons of deuterium at momentum transfer $-t \leq 1.5$ $(GeV/c)^2$ can be described by single and double scattering mechanisms. Single scattering, where only one nucleon participates in the interaction, dominates in transferred momentum range $-t \leq 0.4$ $(GeV/c)^2$. The t – dependence in this case will follow the deuteron form factor. In transferred momentum range $-t > 0.4$ $(GeV/c)^2$, the rescattering mechanism dominates, where photon interacts with one of the nucleons inside the target, produces an intermediate hadronic state which subsequently rescatters from the second nucleon before forming the final state vector meson.

Mechanism of coherent production of ϕ meson on deuterium was studied using CLAS photoproduction data on deuterium for incoming photon energies up to 3.6 GeV [2]. In this analysis coherent photoproduction of $\pi^+\pi^-$ pairs is studied in order to obtain information on coherent ρ^0 production in the reaction $\gamma + d \to d + \rho^0$ with $\rho^0 \to \pi^+\pi^-$. In the analysis of coherent ρ^0 production, t-dependence of the cross section will be studied for different photon energy bins ranging from 1.1 GeV to 5.75 GeV. Number of ρ^0 events will be extracted from fits to the invariant mass distributions of $\pi^+\pi^-$ pairs in each kinematic bin. Here we present method of identification of coherent $\pi^+\pi^-$ production of deuterium. Analysis uses data from CLAS "eg3" experiment [3]. Experiment run with tagged bremsstrahlung photon beam of up to 5.75 GeV and 40 cm long liquid deuterium target.

Data analysis. In the analysis only final states with two positive and one negative particles were considered. It was assumed that the heaviest positive particle (as defined by the CLAS time-of-flight system [4]) is a deuteron. Other two tracks were considered as π^+ and π^- mesons. The first simple requirement to identify the reaction is to have all detected particles originated from the same region of the target and have close relative distance between their vertexes. Fig. 1a presents Z-vertex (along the beam line) distribution of π^+ mesons. The nominal length of the eg3 liquid deuterium target is 40 cm. Target cell was aligned along the beam to have liquid deuterium between Z = -70 cm and Z = -30 cm. CLAS tracking resolution for Z-vertex determination for π^+ is ~ 0.5 cm. This was determined from the fit to a thin, 15 μm, Al foil position at Z = -16 cm. In order to avoid events that are produced in the target cell windows, it was required to have π^+ Z-vertex in the range from -68.5 cm to -31.5 cm (3σ into the liquid target from positions of the target cell windows). These cuts are shown with bold lines in Fig. 1a. Distribution of the difference between Z-vertexes of π^+ and π^- is shown in Fig. 1b. Distribution is fitted with Gaussian function. The bold lines at ± 2.4 cm correspond to $\pm 3\sigma$ cut on this difference for selection of $\pi^+\pi^-$ pairs produced from the same vertex position.

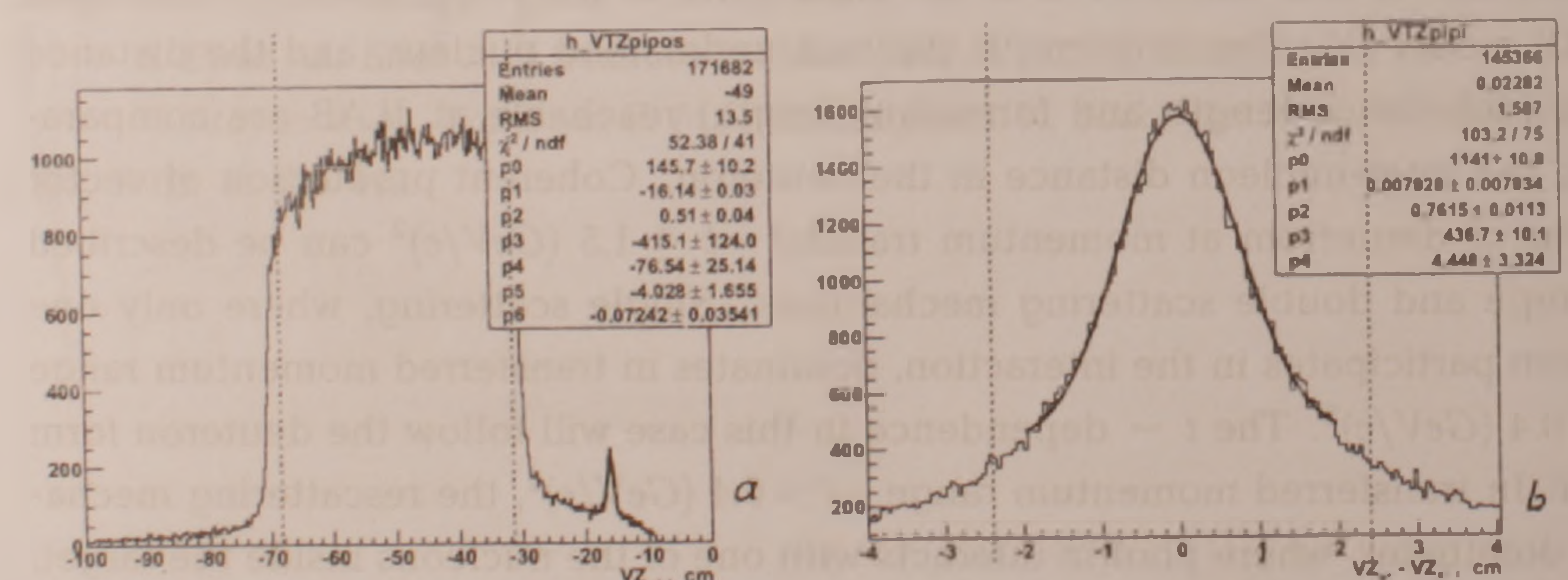

Figure. 1. a - The vertex Z — distribution of the positive pions. Red lines show the region of target selected for data analysis. b - Distribution of Z-vertex difference for positive and negative pion pairs, $\pm 3\sigma$ cut for event selection is shown by bold lines.

According to simulations, in the kinematic region of interest in the reaction $\gamma + d \rightarrow d + \rho^0$ the recoil deuteron will have momentum less than 1.5 GeV. In Fig. 2a momentum distribution of heaviest positive particle, which is assumed to be a deuteron, is presented. A cut on momentum < 1.5 GeV have been applied to select deuterons that are most relevant for this analysis. Note that at high momenta the separation of deuterons and protons is more difficult.

If the detected particles originate from the same reaction they should have the same time of origination or as often it is called, the same vertex time. The vertex time, t_V, of a particle with measured momentum p and nominal mass m is calculated in the following way:

$$t_V = t - \frac{R}{\beta c}, \tag{1}$$

where t is the time measured in the time-of-flight counter where particle is detected, R is the path length of the particle from the production vertex to the time-of-flight counter, c is the speed of light, and $\beta = p/\sqrt{p^2 + m^2}$ is the particle velocity. Vertex times for all final state particles were calculated using measured momenta and assumed nominal masses. If the hypothesis on the particle type (mass) is right then the difference of vertex times of final state particles should be zero. The main background to the hypothesis made above for type of three final state particles, $\pi^+\pi^-d$, is the final state $\pi^+\pi^-p$, where proton can be miss identified as a deuteron.

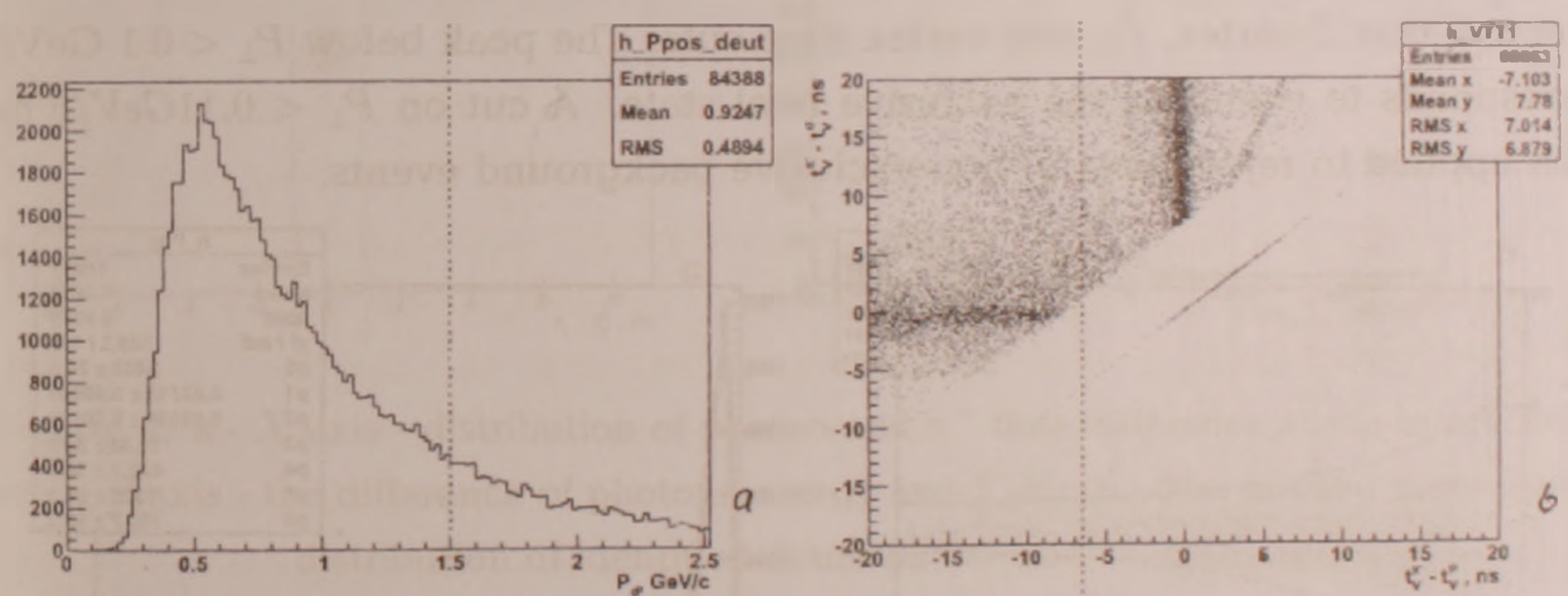

Figure. 2. a - The distribution of momenta of potential deuterons. b - The vertex time differences between π^- and the positively charged heaviest particle assuming it is a deuteron on Y axis, and with assumption that it is a proton on X axis. On both graphs selection cuts are indicated with bold lines.

In Fig. 2b the vertex time differences of π^- and the heaviest positively charged particle are plotted with two assumptions. On Y-axis is the difference when a positively charged particle is assumed to be a deuteron, on X-axis positively charged particle is assumed to be a proton. Events distributed around zero on X axis correspond to cases when heaviest positive particle is a proton. Events with vertex time difference at zero on Y-axis are final states with deuteron. In order to select events for coherent $\pi^+\pi^-$ pairs production, analysis cut $t_\pi - t_p < -6.5$ ns was applied (cut difference at zero on Y-axis are final states with deuteron. In order to select events for coherent $\pi^+\pi^-$ pairs production, analysis cut $t_\pi - t_p < -6.5$ ns was applied (cut shown with bold line in Fig. 2b). While the main part of the background due to deuteron misidentification is above the cut, due to accidentals and time resolution tails, misidentified deuterons can occur below the cut as well. For further reduction of the background due to misidentification of deuterons, cut on the vertex time difference between π^- and d is applied. The time difference is momentum – depended and at low momentum range effected by energy loss in the target. In Fig.3a π-d vertex time difference is plotted versus deuteron momentum. Two red dashed curves indicates applied mean$\pm3\sigma$ cut, where the mean and σ were determined after fitting the vertex time difference in a small momentum bins with Gaussian function.

Since we are considering fully exclusive reaction, where all outgoing particles are detected, the total four momentum of detected final state particles should be equal to the total momentum of incident particles. Therefore, the total perpendicular momentum in the final state should be zero, $P_\perp = 0$, where $P_\perp = \sqrt{P_x^2 + P_y^2}$ is constructed from the perpendicular components of momenta of final state particles $P_x = \sum_i P_x^i$ and $P_y = \sum_i P_y^i$, $i = d, \pi^+, \pi^-$. In Fig. 3b the distribution of $P_\perp$ for events selected after Z-vertex, P_d, and vertex time cuts. The peak below $P_\perp < 0.1$ GeV/c corresponds to events in the exclusive final state. A cut on $P_\perp < 0.11 GeV/c$ has been applied to reject most of non-exclusive background events.

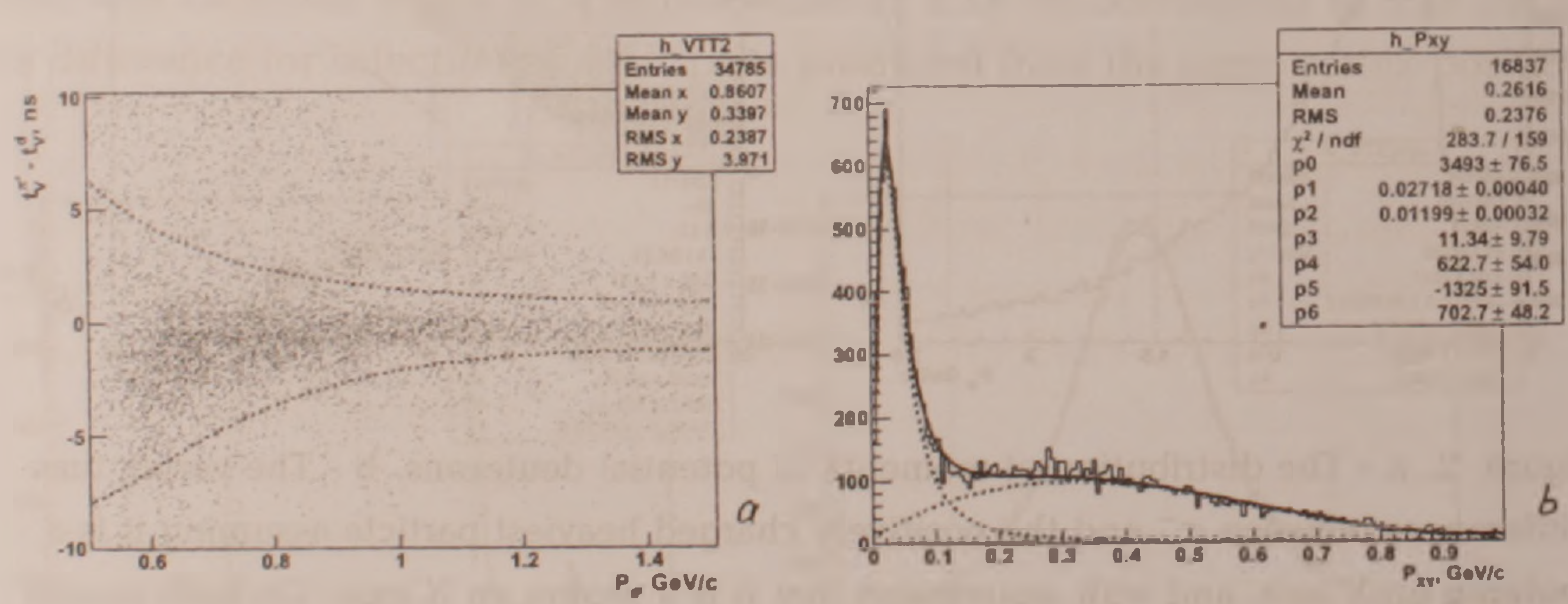

Figure. 3. a - Vertex time difference between π^- and d depends on deuteron momenta, bold dashed curves indicate the cut region. b - The distribution of the perpendicular momenta of final state particles after vertex time cut between π^- and d.

In high intensity photoproduction experiments within the coincidence time window between CLAS and the photon tagger [5] (~ 15 ns), more than one photon can be detected. The standard way to identify the photon that produced triggered event in CLAS is shrinking the coincidence time window down to less than 2 ns.

This time window is defined by the accelerator RF frequency that is 1497 MHz. Every third bunch is sent to each of the experimental Halls, making frequency of the beam on the target 499 MHz, or every 2.004 ns. Probability of having more than one tagged photon from the same beam bunch is very low. Therefore timing cut < 2 ns between vertex time of a particle detected in CLAS and the time of photon interaction with the target is a powerful cut to select right photon in the tagger.

For a fully exclusive final state there is another constraint for selecting the right photon in the tagger. The sum of Z-components of momenta of detected particles should be equal to the energy of incoming photon. In Fig. 4a $E_\gamma - \sum P_Z^i$ is plotted versus the vertex time difference between π^- and the photon in the tagger. One can clearly see vertical bends in 2 ns intervals. The bend at zero has large concentration at $E_\gamma - \sum P_Z = 0$, that corresponds to events for fully exclusive $(\pi^+\pi^-d)$ final state with correct photon selected. Events within ± 1 ns interval were selected for further analysis.

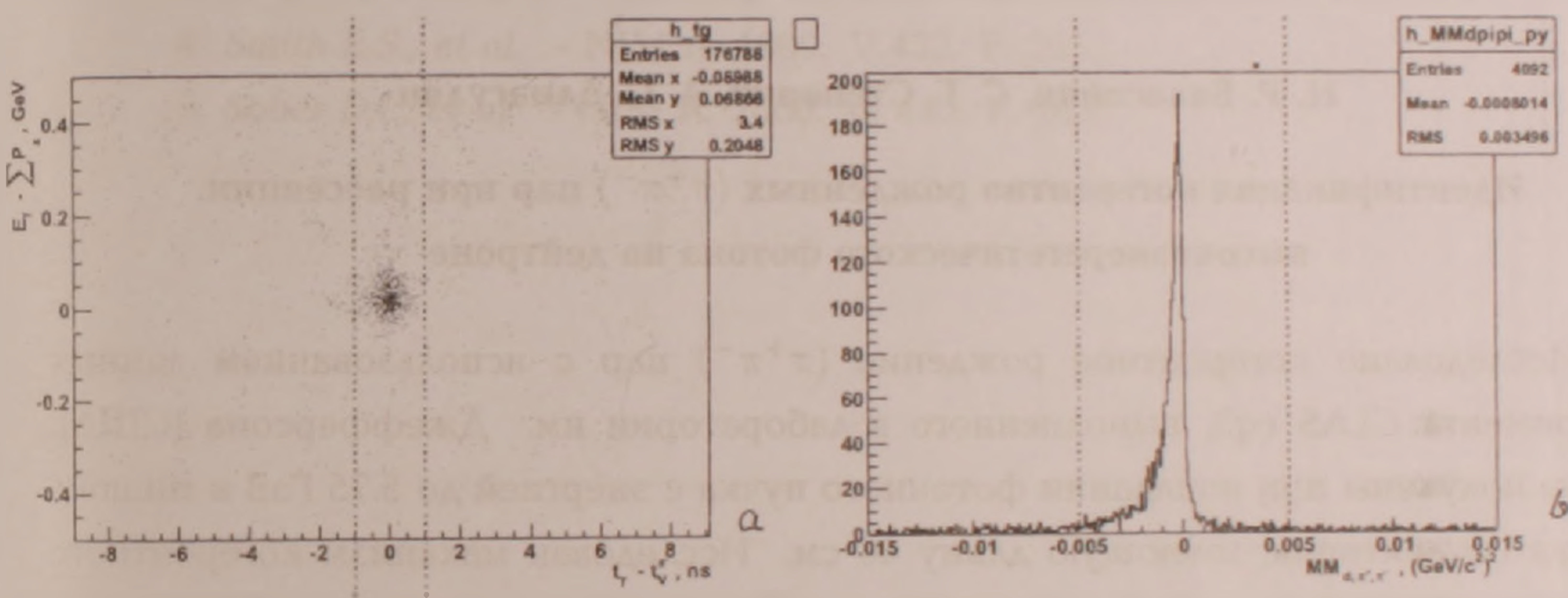

Figure. 4. a - X axis - distribution of photon and π^- time difference at the interaction vertex, Y axis - the difference of photons energy and $\sum P_Z$. b - The missing mass square distribution of identified deuteron, π^+ and π^- system.

After selecting the right photon in the tagger, the missing mass of the detected final state is studied, see Fig. 4b. The final cut for selection of the fully exclusive final state $\pi^+\pi^-d$ was performed on the missing mass and was ± 0.005 GeV^2.

Summary. In this work criteria for selection of events in coherent photoproduction of $\pi^+\pi^-$ pair on deuterium are developed. For analysis, data from eg3 experiment at Jefferson Lab are used. It is shown that cuts on the vertex time, on the perpendicular momentum, and on the total energy sum are crucial for selecting $\pi^+\pi^-d$ final state events. This final state will be used to investigate dynamics of coherent ρ^0 photoproduction reaction on deuterium.

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Identification of Coherent $(\pi^+\pi^-)$ Pairs Production in High Energy Photon-Deuteron Scattering

Coherent production of $(\pi^+\pi^-)$ pairs is studied using data from CLAS eg3 experiment at Jefferson Lab (USA). Data were acquired with up to 5.75 GeV tagged photons incident on 40 cm long liquid deuterium target. Physical motivation for this study is the investigation of the mechanism of coherent photoproduction of vector mesons, in particular ρ^0-mesons, off the deuteron. In this paper we discuss the data sample and the selection criteria of coherent scattering events in fully exclusive reaction $\gamma d \to \pi^+\pi^- d$. It is shown that exclusivity cuts, using energy and momentum conservation, and production vertex timing cuts are crucial for clean separation of coherent $(\pi^+\pi^-)$ pair production from physical background arising mostly from scattering off the proton in deuterium.

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Идентификация когерентно рожденных $(\pi^+\pi^-)$ пар при рассеянии высокоэнерегетического фотона на дейтроне

Исследовано когерентное рождение $(\pi^+\pi^-)$ пар с использованием данных эксперимента CLAS eg3, выполненного в лаборатории им. Джефферсона (США). Данные получены при попадании фотонного пучка с энергией до 5.75 ГэВ в мишень из жидкого дейтерия, имеющую длину 40 см. Исследован маханизм когерентного рождения векторных мезонов, в частности, ρ^0 мезонов, на дейтроне. Обсуждены критерии выделения когерентно рассеянных событий в эксклюзивной реакции $\gamma d \to \pi^+\pi^- d$. Показано, что эксклюзивные отрезки с учетом закона сохранения энергии и импульса, а также отрезки времени рождения частиц имеют рещающее значение при выделении когерентного рождения $(\pi^+\pi^-)$ пар из физического фона, обусловленного, в основном, рассеянием на протоне, находящемся в составе дейтрона.

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Կոհերենտ ծնված $(\pi^+\pi^-)$ զույգի նույնականացումը բարձր էներգիայով ֆոտոնի դեյտրոնից ցրման ժամանակ

Ջեֆֆերսոնի անվան լաբորատորիայում (ԱՄՆ) իրականացված CLAS eg3 գիտափորձի տվյալների հիման վրա հետազոտվել է $(\pi^+\pi^-)$ զույգի կոհերենտ ֆոտոծնումը: Տվյալների հավաքագրումը կատարվել է մինչեւ 5.75 ԳէՎ էներգիայով ֆոտոնների փոխազդեցությունը

հեղուկ դեյտերիումի 40 սմ-նոց թիրախի հետ դիպարկելիս: Ֆիզիկայի տեսանկյունից աշխատանքի հիմնավորումը դեյտրոնի վրա վեկտոր մեզոնների՝ մասնավորապես ρ^0 մեզոնների, կոհերենտ ֆոտոծնման մեխանիզմի ուսումասիրությունն է: Քննարկված են $\gamma d \to \pi^+\pi^- d$ ռեակցիայում կոհերենտ մասնիկների ընտրման չափանիշները: Ցույց է տրված, որ էքսկլյուզիվ ռեակցիայի պայմաններում էներգիայի եւ իմպուլսի պահպանման օրենքի օգտագործումը, ինչպես նաեւ մասնիկների ծնման ժամանակի համար տրված սահմանափակումը կարեւոր նշանակություն ունեն կոհերենտ ծնված $(\pi^+\pi^-)$ զույգի տարանջատման համար՝ դեյտրոնի կազմի մեջ մտնող պրոտոնի վրա ցրումից առաջացող ֆիզիկական ֆոնից:

References

1. *Sakurai J. J.* - Phys.Rev.Lett. 1969. V.22. P. 981.
2. *Mibe T., et al.* - Phys.Rev.C. 2007. V.76. P. 052202-1.
3. *http://www.jlab.org/exp_prog/generated/apphallb.html, E04-010.*
4. *Smith E.S., et al.* - NIM A. 1999. V.432. P. 265.
5. *Sober D.I., et al.* - NIM A. 2000 V. 440. P. 263.