

STUDY OF $\Delta(1232)$ ISOBAR ELECTROPRODUCTION AT VEPP-2M e^+e^- -COLLIDER

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Submitted 6 April 1998

Results from the Spherical Nonmagnetic Detector (SND) on $\Delta(1232)$ isobar electroproduction in the collisions of beam electrons (positrons) and residual gas nuclei in the VEPP-2M e^+e^- -collider are presented. On the basis of the obtained data the expected counting rate of this process in future high luminosity e^+e^- -colliders (ϕ , c - τ - and b -factories) was estimated.

PACS: 14.20.Gk, 13.60.Rj

Electron or positron beam propagating along the collider beam pipe can produce pions on nuclei of residual gas atoms. At a beam energy of $E_0 \approx 500$ MeV (ϕ -factory region) the main source of such pions is an electroproduction of $\Delta(1232)$ $I(J^P) = 3/2(3/2^+)$ isobar state [1]. In an electron-nucleus collision a nucleon can convert into either Δ^+ ($ep \rightarrow e\Delta^+$) or Δ^0 ($en \rightarrow e\Delta^0$) with a subsequent decay of $\Delta(1232)$ into nucleon and pion: $\Delta^+ \rightarrow p\pi^0, n\pi^+$; $\Delta^0 \rightarrow p\pi^-, n\pi^0$. The total number of produced π^0 is twice higher than that of π^+ or π^- . At an electron energy of about 500 MeV cross section of the isobar electroproduction is proportional to A , atomic weight of the target. But only those Δ -isobars, which were produced on the nucleus surface, would actually decay into $\Delta \rightarrow N\pi$. For Δ -s, produced inside the nucleus the $\Delta N \rightarrow NN$ reaction dominates. It means that the $eN \rightarrow e\Delta$, $\Delta \rightarrow \pi N$ cross section must be proportional to $A^{2/3}$.

The total cross section of the isobar electroproduction on a nucleon at electron energy of 510 MeV is about $3 \mu\text{b}$. This reaction is a possible source of background at ϕ -factories [2]. It can be also an actual background in experiments at higher energies (its total cross section is about $8 \mu\text{b}$ at a $c - \tau$ -factory and $12 \mu\text{b}$ in the b -factory energy region). This paper presents results of experimental study of $\Delta(1232)$ electroproduction with SND detector at VEPP-2M e^+e^- -collider in Novosibirsk. SND detector [3] consists of a drift chamber tracking system with an angular resolution $\sigma_\theta = 2.2^\circ$, $\sigma_\phi = 0.7^\circ$ and dE/dx resolution of about 30%, a three layer NaI(Tl) spherical electromagnetic calorimeter [4] with an angular resolution $\sigma_\theta = \sigma_\phi = 1.5^\circ$ and energy resolution $\sigma_E/E = 4.2\%/\sqrt{E(\text{GeV})}$ for photons, and a muon identification system. The Δ -isobar electroproduction process was studied in $ep \rightarrow e\Delta^+$, $\Delta^+ \rightarrow p\pi^0$ channel, because of its very distinct signature: two photons from π^0 -meson decay and two tracks from electron and proton. It is important that in this case photon energies and invariant masses are known and electron/proton

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separation based on dE/dx measurements in the drift chambers is possible. Monte Carlo simulation of the Δ -isobar electroproduction on a single proton, based on formulae from [2], was used for studying selection criteria and detection efficiency. Passage of particles through the detector was simulated using UNIMOD2 code [5].

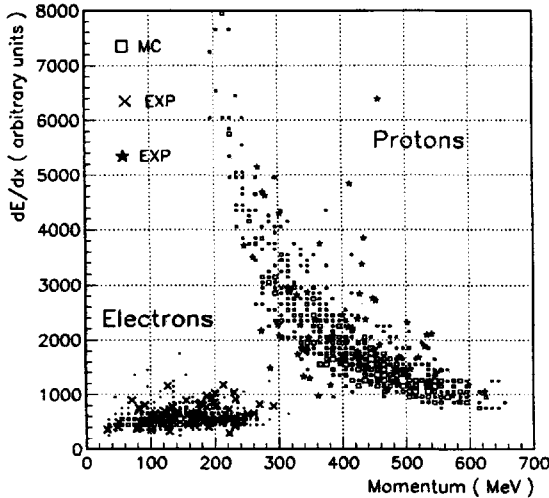


Fig.1. dE/dx , specific ionization losses of electrons and protons, produced in $\Delta(1232)$ decays. Crosses - electrons, stars - protons

Experimental data collected in 1996 in the energy range $2E_0 = 1.00 \div 1.04$ GeV [6], with an integrated luminosity of $L = 0.5 \text{ pb}^{-1}$ were processed. Events with two charge particles and two photons were selected for further analysis. To suppress the background from decays of copiously produced ϕ -mesons ($\phi \rightarrow 3\pi, K_S K_L, K^+ K^-$, etc.) the following selection criteria were applied: total energy deposition in the calorimeter is less than the beam energy E_0 , the angle between charged particles is smaller than 150 degrees, which greatly reduces $K^+ K^-$ and $K_S K_L$ background, and dE/dx of one of the charged particles is at least twice larger than that of a minimum ionizing particle. Coordinate of a Δ -isobar production point along the beam was reconstructed using charged particles tracks. Then the kinematic fit was performed under following constraints: the particle with a larger dE/dx was considered as proton; total transverse momentum $p_{\perp} = 0$; longitudinal momentum $p_{\parallel} = E_0/c$, photons originate from $\pi^0 \rightarrow \gamma\gamma$ decay, and the total energy $E = E_0 + m_p c^2$, where m_p is a proton mass. Eighty events consistent with these assumptions were found. Their production points are uniformly distributed along the beam direction within 20 cm fiducial length in contrast with background, peaked at the beams collision point. The dependence of dE/dx on reconstructed charged particle momentum is shown in Fig.1. Electrons and protons are well separated and momentum dependence of the proton specific ionization losses is clearly seen. The characteristic feature of the $\Delta \rightarrow \pi N$ decay is that π -mesons are emitted at large angles with respect to the beam direction [2]. The experimental and simulated distributions, shown in Fig.2 are in a good agreement. The proton-pion invariant mass spectra (fig.3) are peaked between $1200 \div 1250$ MeV. The peaks are located at 1218 ± 6 MeV and 1235 ± 2 MeV in experimental and simulated distributions respectively. The expected number of selected

experimental events can be written as:

$$N = \frac{I}{e} t \sigma N_p l \epsilon,$$

where $I = 30 \text{ mA}$ is an average beam current, e - electron charge, $t = 7 \cdot 10^5 \text{ s}$ - total data acquisition time, $l = 20 \text{ cm}$ - fiducial length, $\sigma = 2 \mu\text{b}$, N_p - effective density of protons, $\epsilon = 0.026$ - detection efficiency. Number of observed experimental events is $N = 80 \pm 9$ (statistical) ± 10 (systematic). It corresponds to $N_p = 6 \cdot 10^{14}/\text{m}^3$. The residual gas pressure $P = nkT$, where k is the Boltzmann constant, $T = 300 \text{ K}$ and n is the density of residual gas molecules. The expected composition of the residual gas is H_2 - 30%, CH_4 - 10%, CO - 20% and CO_2 - 40%. In this case $N_p = 6n$, and P , calculated using expression (1), is equal to 3 ± 0.4 (statistical) ± 2 (systematic) nTorr. This value agrees with direct pressure measurements: $P = 3 \pm 2$ nTorr. The large systematic error in the former value is due to uncertainty in residual gas composition. At DAΦNE ϕ -factory [7] ($I = 5 \text{ A}$, $P = 1 \text{ nTorr}$) the rate of $e p \rightarrow e \Delta^+$, $\Delta^+ \rightarrow p \pi^0$ reaction is $\sim 1.2 \text{ Hz/m}$. Taking into account $\Delta^+ \rightarrow n \pi^+$ decay and Δ^0 electroproduction on the neutrons the counting rate raises up to 4 Hz/m . This value agrees with estimation in [2]. ϕ -Factory experimental program includes CP -violation in kaon decays, rare decays of ϕ -meson, two-photon processes and $e^+e^- \rightarrow$ hadrons annihilation at low energies [8]. The $\Delta(1232)$ electroproduction process could be considerable source of background, for instance, for two-photon processes (the counting rate for $\gamma\gamma \rightarrow \pi^0$ is expected to be 0.2 Hz) [9]. Its counting rate is also comparable with the rate of the ϕ -meson rare decays $\phi \rightarrow \gamma\eta$, $\gamma f_0(980)$, $\gamma a_0(980) \leq 0.5 \text{ Hz}$, or with $K_L \rightarrow \pi\pi$ decays $\leq 2 \text{ Hz}$. On the other hand $\sim 4 \cdot 10^7$ events of $\Delta(1232)$ decays would be produced at the ϕ -factory per effective year (10^7 s) per one meter of fiducial length.

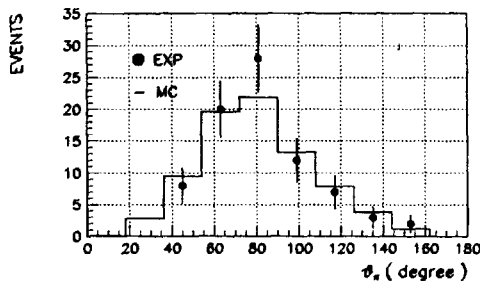


Fig.2. The π^0 -polar angle distribution in $\Delta(1232)$ decay

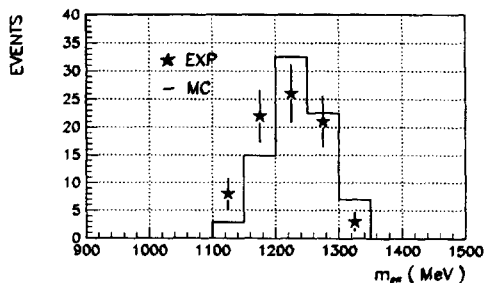


Fig.3. The $p\pi^0$ -invariant mass distribution in the process of $\Delta(1232)$ electroproduction

This means, that in addition to e^+e^- -physics, experiments in the field of nuclear physics, e.g. studies of collective effects in nuclei (so-called Δ - h states [10]), are possible. This work was supported in part by the Russian Foundation of Basic Research, Grant 96-15-96327, 97-02-18561, and by International Scientific Foundation, Grant RPX000 and RPX300.

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