CEBAF PROPOSAL COVER SHEET

This Proposal must be mailed to:

CEBAF
Scientific Director's Office
12000 Jefferson Avenue
Newport News, VA 23606

and received on or before OCTOBER 31, 1989

. TITLE:

Measurements of the Electroproduction of Λ(gnd), Λ^*(1520) and f_o(975) via the K^+K^-p and $K^+ \; ^-p$ Reactions

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. THIS PROPOSAL IS BASED ON A PREVIOUSLY SUBMITTED LETTER OF INTENT

/X/ YES
/ / NO

IF YES, TITLE OF PREVIOUSLY SUBMITTED LETTER OF INTENT

Photo and Electro production of K^+K^-p and $\pi^-\pi^+p$ final states.

. ATTACH A SEPARATE PAGE LISTING ALL COLLABORATION MEMBERS AND THEIR INSTITUTIONS

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contact: Dennis

Study of Electromagnetic Excitation of Baryon Resonances with the CEBAF Large Acceptance Spectrometer

The N* Collaboration

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Proposal 7

Measurements of the Electroproduction of the Λ(gnd), $\Lambda^*(1520)$ and $f_0(975)$ via the K^+ K^- p and K^+ π^- p final states.

A PROPOSAL SUBMITTED TO THE C.E.B.A.F. PROGRAM ADVISORY COMMITTEE

by

The N* Group of the C.L.A.S. collaboration

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Abstract

It it is proposed to use the CEBAF Large Acceptance Spectrometer (CLAS) in a series of measurements to study exclusive electroproduction and charged hadronic decay of the $f_0(975)$ resonance and low-mass lambdas. Hadron polarization and interference effects will be determined by measurement of the decay angular distribution multipole moments. The resulting measurements will:

i) test models of the structure of the f_0, the lowest mass isoscalar member of the scalar meson nonet - whether it is a "conventional" $^3P_0$ $q\bar{q}$ system modified by K thresholds or a member of a group of $qq\bar{q}\bar{q}$ states or possibly a unique "mesonic nucleus"-like $q\bar{q}-q\bar{q}$ system;

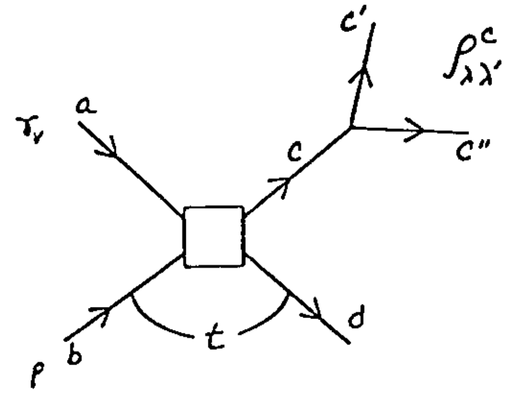
ii) determine which hadronic s, t, and u channel contributions are important in ΛK production by using final state Λ polarization to help isolate specific contributions.

These measurements, which will detect 3 of the 4 charged particle final states, are proposed as first round experiments and will use the same CLAS event data as non strange baryon electroproduction studies which are addressed in other portions of the N^* collaboration proposal.

Due to the average overall acceptance of the CLAS for the three particle final states of no less than 3%, and assuming a luminosity of 10^{34}, one can expect a detectable production rate of about 1600 events/hour for the Λ and 1100 events/hour for the $\Lambda^*(1520)$ and 400 events/hour for the f_0. Data for both of these measurements can be accumulated simultaneously and it may be possible to also make these measurements simultaneously with other measurements described in the N^* collaboration proposal.

Physics Motivation

Because of the CLAS acceptance for 3 and 4 particle final states it is possible to deduce the polarization of outgoing decaying hadrons and interference effects from their center-of-mass decay angular distribution (multipole moments), shown schemetically below, and the corresponding statistical tensor, $T^{c}_{LM}(\Omega^{*})$ from which the spin density matrix, $\rho^{c}_{\lambda\lambda'}$, of the decaying hadron can be obtained. In order to obtain this information, it is necessary that at least 3 of the four final state particles be detected in order to completely kinematically determine the reaction.



The two types of reactions to be studied with this method are:

(1)
$$\gamma_v + p \rightarrow \underbrace{m_1^+ + m_2^-}_{\rho^c_{\lambda\lambda'}(meson)} + p$$

and

(2)
$$\gamma_v + p \rightarrow m_1^+ + \underbrace{m_2^- + p}_{\rho^c_{\lambda\lambda'}(baryon)}$$

In 1), $m_{1,2}$ are K mesons from the $f_0(975)$ decay. In 2), m_1 is a K meson, m_2 is a π for the Λ(gnd) decay and a K meson for the $\Lambda(1520)$ decay. CLAS electroproduction measurements of hadron decay multipole moments of the above two types of 3 charged final state hadrons can in principal be extended to other baryons and mesons, such as the $\Delta(1232)$, $f_2(1270)$, and $f_2'(1525)$

The measurements of decay multipole moments in the two proposed reactions involving strangeness will both use the same set of CLAS event data. The reactions are proposed because they have presented puzzles which are described below:

1) $f_0(975)$ production

The motivation for electroproduction of the $f_0(975)$ meson (S^* under the old naming scheme) is that its quark structure is uncertain. It, together with the $a_0(980)$ (old $\delta(980)$, $f_0(1400)$,(old $\epsilon(1300)$), and $K_0^*(1430)$ (old $\kappa(1350)$) are considered to be[12] one of the two isoscalar members of the nonet $^3P_0$ ($q\bar{q}$ in a relative L=1 state). While the lower lying pseudoscalar and vector mesons in the $^1S_0$ and $^3S_1$ nonets are well explained, there has been difficulty in describing the $^3P_0$ nonet as the L=1 complement of the lower mass L=0 nonets. Observed masses and widths disagree with the expected properties of a $^3P_0$ $q\bar{q}$ system. In particular, the $f_0(975)$, has considerbly less mass than expected; its mass nearly equals that of the $a_0(980)$, (old $\delta(980)$), whereas its expected mass should be 200 Mev higher due to its apparent $s\bar{s}$ structure, in analogy to the ρ and ϕ of the $^3S_1$ nonet. Its width expected to be approximately that of the the $K_0^*(1430)$ is measured to be only 10% of it.

The $f_0(975)$ has been suggested at various times to be a glueball[1)], a $qq\bar{q}\bar{q}$ "exotic"[2)] and a very weakly bound $q\bar{q}$ - $q\bar{q}$ "mesonic-nucleus"[3,4)]. The latter authors also suggested that it may be the only example of this type of four quark configuration. If the state is a weakly bound four quark configuration, is is relatively large, about 1.5 times the size of a pion. Hence its cross section could have a readily discernable behavior with Q^2.

The "conventional" $q\bar{q}$ $^3P_0$ structure can explain some of the above discrepencies when K thresholds are incorporated into the calculation[12]. A recent e^+e^- experiment13 at 29 GeV has multiplicity data that is consistant with the $q\bar{q}$ structure, although it cannot rule out a $q\bar{q} - q\bar{q}$ structure.

Two lower energy photoproduction experiments7,8 have been done which identify the 0+ $f_0(975)$ signature by its interference with the strong 1- $\phi(1020)$ amplitude produced mostly by vector meson dominance diffractive process. Both mesons have a large K^+K^- decay branch. The statistical tensors, $T^{\epsilon}_{LM}(\Omega^*)$, formed from the decay multipole moments, choosing the s-channel helicity frame for the z-axis direction, show a rapid invariant K^+K^- mass variation of the L,M = 1,0 interference component near the $\phi(1020)$ mass. Analysis of the data shows the most likely fit to be produced by the $f_0(975)$. It is 90^0 out of phase with the $\phi(1020)$ and hence non diffractive. The cross section, at $\approx$ 4 GeV photon energy, is $\approx$ 100 nb. Because of low count rates, sums had to be taken over photon energy and t.

We propose to electroproduce the $f_0(975)$ and observe it by the above L,M = 1,0 interference. As noted below, CLAS will obtain sufficient events to perform W and t analysis in addition to determining the virtual gamma Q^2 and longitudinal/transverse dependence of the electroproduction. If the $f_0(975)$ is a large weakly bound "mesonic nucleus"[3], the Q^2 and t variation of the cross section should display this effect.

2) $K^+\Lambda(gnd)$ and $K^+\Lambda(1520)$ production

Since Λ production is associated with K^+ production, t-channel processes are large. However, in contrast to pion production, there is no one dominantly low mass exchanged K. Furthermore, the lowest mass K^+, at 0.5 GeV with spin 0 is longitudinally produced whereas the next higher mass K^{*+} at 0.9 GeV with spin 1 is mainly transversally produced. Hence there is a preference for $K^{*+}(892)$ t-channel exchange. Fits to Λ photo and electroproduction indeed indicate substantial $K^{*+}(892)$ exchange, but the fits must additionally include $K_1(1280)$ and/or Regge t-channel exchanges plus p and N^* s-channel and Λ and excited Λ u-channel exchanges. However, the only electromagnetic production experiment[5] measuring polarization, that of photoproduced $\Lambda(1520)$, indicated predominately $K^{*+}(1520)$ t-channel exchange. An inclusive electroproduction experiment[6], however, indicates a substantially different Q^2 dependence of the cross section between the $\Lambda(gnd)$ and the $\Lambda(1520)$ with the $\Lambda(1520)$ (and the Σ(gnd)) having the more rapid fall off in cross section with Q^2. However this conclusion depends critically on the absolute value of the electro cross-section results relative to that measured in photoproduction. A subset of the existing data which illustrates this is shown in Fig. 1.

We are proposing to study the Q^2 dependence of the spin density matrices of the $\Lambda^*(1520)$ as determined by the K^-p decay and of the $\Lambda(gnd)$ as determined by the π^-p decay. The spin density matrices for these decays can help determine the contributions of the several production graphs. By suitable choice of multipole moment z-axis, (e.g. Jackson-Gottfried, helicity frames), the exchange particle spin can possibly be identified. If a specific t-channel can be isolated, an electromagnetic form factor of the exchanged particle can then be obtained.

Feasability of the Proposed Experiments

Production Rates

The production rates for the $\Lambda, \Lambda^*(1520)$ and the f_0 are given in the table below. These rates assume a luminosity of 10^{34}.

Estimated Production Cross Sections

Particle	Cross Section at Photopoint	Gamma Vertex Flux Factor	Branching Ratio	Production Rate
Λ	700 nb	$3.6 \cdot 10^{-3}$	0.64	16 Hz
$\Lambda^*(1520)$	700 nb	$3.6 \cdot 10^{-3}$	0.45	11 Hz
f_0	100 nb	$2.0 \cdot 10^{-2}$	0.22	4 Hz

The photopoint cross sections used above were obtained from ref. 5 for the $\Lambda^*(1520)$, from ref. 6 for the Λ and from ref. 7 and 8 for the f_0.

Acceptance and Resolution of the Detector

Acceptance and resolution studies of the CLAS detector were carried out using the computer programs GLAS[9], CELEG[10] and FASTMC[11]. These programs allow one to estimate the response of the detector to these reactions and to examine any background reactions. The reactions e + p → e' + X were modeled assuming an isotropic decay of X into either $K^+ + \Lambda$, $K^+ + \Lambda^*(1520)$ or $p + f_0$. The Λ, $\Lambda^*(1520)$ or f_0 was then assumed to decay isotropically. Though not ideal, this allows an estimate of the response of the detector to these reactions. Figure 2 shows the results of a GEANT simulation of a $\Lambda^*(1520)$ production and decay, as it appears in the CLAS. Figure 3 shows the acceptances obtained for three and four particles reaching the scintillators, as a function of Q^2 and W. In each case, the electron was required to be one of the particles which reached the scintillators. In principle, it is not necessary for the electron to be detected, however it is necessary to reduce the trigger rate to an acceptable level. The acceptances shown in Figure 3 represent a lower limit to the acceptance, since they require that all "detected" particles reach the scintillators. Some particles can be reconstructed using momentum and $\frac{dE}{dx}$ information, if they reach at least the first two chambers. In addition, some improvement in the acceptances is expected if the magnetic field is reduced below its maximum value. Requiring two or more particles to hit the scintillators will modify the triggering scheme, the acceptance and the resolution. For these experiments, such modifications have not been fully studied.

Using FASTMC it was possible to predict the resolution one would obtain in the missing mass spectrum. Figure 4(a) shows the results of a FASTMC reconstruction of "background" events. The results obtained for the $\gamma_v + p \rightarrow K^+\Lambda^*(1520) \rightarrow K^+ + K^- + p$ and $\gamma_v + p \rightarrow p + f_0(975) \rightarrow p + K^+ + K^-$ are shown in figure 4(b). If all the particles in the event can be identified correctly, then the missing mass resolution of about 30 MeV makes it very difficult to misidentify the events of interest. When some particles are misidentified the ability to cross check the reaction using the energy and momentum of two different pairs of particles is extremely effective in reducing background.

Triggering and Particle Identification

In the proposed reactions it is essential that at least three of the four final products be measured. This is necessary to extract the physics of interest and also to select the events of interest from the large "background" of other reactions. The table below shows estimated rates for the various trigger levels under different trigger conditions. The numbers in the table assume the cross section for $e + p \rightarrow e' + X$ is about 200 μb for $12° \leq \theta_e \leq 45°, 0.1 \leq Q^2 \leq 3.0$ and $.935 \leq W \leq 3.0$. The total cross sections assumed for Λ and $\Lambda^*(1520)$ production were both 700 nb[5,6] and the total cross section for $f_0(975)$ production was assumed to be 100 nb[7]. The luminosity used was 10^{34}. The drops in the rates from level to level are based on estimates of the fraction of the events which meet the requirements of that level trigger. These fractions were estimated using known branching ratios, CELEG and FASTMC. Much of the information used can be obtained from Figures 5 and 6, which show, respectively, the distributions of the number of particles which hit a scintillator per event and the types of particles which make up the coincidences. Figure 7 shows the experimentally obtained missing mass distribution. The absence of contaminant reactions can be used in the Level 4 trigger as a very efficient event selector. Figure 8 shows a typical time of flight vs momentum distribution which can usually be used to identify kaons and protons of the required momemtum.

Estimated Event Rates (counts/second)

	Number of Particles Hitting Scintillators			
	1	2	3	4
LEVEL 0 (Raw Production Rate)				
Background Rate	2,000,000	2,000,000	2,000,000	2,000,000
Reaction Rate	30	30	30	30
Total Rate	2,000,000	2,000,000	2,000,000	2,000,000
LEVEL 1 (N scintillator hits and 1 Cerenkov hit)				
Background Rate	60,000	50,000	4000	200
Reaction Rate	12	8	0.81	0.08
Total Rate	60,000	50,000	4000	200
LEVEL 2 (Same as above)				
Background Rate	60,000	50,000	4000	200
Reaction Rate	12	8	0.81	0.08
Total Rate	60,000	50,000	4000	200
LEVEL 3 (Approximately correct momentum for kaon or proton)				
Background Rate	42,000	35,000	2,800	140
Reaction Rate	5	3	0.81	0.08
Total Rate	42,000	35,000	2,800	140
LEVEL 4 (Smaller TAC gate and correct missing mass)				
Background Rate	0	5	0.03	0.0014
Reaction Rate	0	0.82	0.81	0.08
Total Rate	0	5.8	0.83	0.081

From the table above it is clear that it is possible to identify the required events with little interference from the large background of events. However, a major hurdle will be to write software which can handle the LEVEL 4 input rate, i.e., software which can quickly reject unwanted events. Since the current estimate is that the processor farm will have a combined CPU capable of about 1000 MIPS, it will be necessary to spend less than an average of 0.3 seconds processing each event (in a 1 MIPS processor). This is only slightly faster than the methods currently being tried within the CLAS collaboration.

Background and Accidentals

Backgrounds for these experiments were estimated using the computer code CELEG in conjunction with FASTMC. Using CELEG, a large number of events was produced for Q^2 values between 0.03 and 3.0 GeV^2 and W values between 0.935 and 3.0 GeV^2. These events were subjected to the same analysis done on the events of interest. Figure 5 shows the distribution of the number of particles which hit the scintillators for two of the sets of sample events. In addition, missing mass spectra were computed for the CELEG generated events, approximately $\frac{1}{10000}$ of these events resulted in a missing mass within 150 MeV of the masses of the f_0 or $\Lambda^*(1520)$.

The accidental rate can be determined from the overall detector count rate detector and the required coincidence resolving time. Using FASTMC[9]) to simulate the response of the CLAS one finds that events in which three or more particles hit the scintillators have less than a 15 ns time spread in their arrival times. Figure 9 shows a typical TAC spectrum obtained from the simulation of particles through the dectector. Thus a very narrow window can be used to select particles which belong to desired events. (Note: The 200 ns which is the "time to decision" for the first level trigger establishes the trigger dead time, not its resolution.) With a 15 ns time window and a raw data rate of about 60,000 Cerenkov-scintillator hits/second and an average of 2 scintillator hits/event one obtains about 100 accidental hits/second. However, these accidentals are a potential problem only if they result in "events" containing more than two particles. Since these accidentals represent a small fraction of the total three or more particle event rate they can be effectively dealt with by the level 4 trigger where tighter timing and energy constrants can be placed on the event.

Run Plan and Beam Time Estimate

In the first round of experiments using the CLAS, we intend to measure the Q^2 dependence and the spin density matrices for the f_0, Λ, and $\Lambda^*(1520)$ using a 4.0 GeV electron beam. The main idea is to detect at least all but one of products in the final state to be able to completely kinematically determine the reaction.

Beam Energy = 4.0 GeV

Missing Mass Energy Resolution = 30 MeV

Range of Q^2 for f_0 is 0.03 GeV^2 to 0.18 GeV^2, the low value being used to test possible $q\bar{q} - q\bar{q}$ "mesonic nucleus" structure of the $f_0(975)$[3,4].

Range of Q^2 for $\Lambda^*(1520)$ is 0.05 GeV^2 to 1.0 GeV^2

Width of Q^2 bins = 0.1 GeV^2 for $\Lambda^*(1520)$ and 0.05 GeV^2 for f_0

Width of W bins = 0.3 GeV

Minimum number of $\theta^* - \phi^*$ bins for measurements of decay multipole moments and interference , using the given spins of the decaying hadrons, = 4

Minimum number of ϕ_e bins to separate L+T,TT, and LT terms of the virtual photon, where ϕ_e = angle between the electron scattering plane and hadron production planes, = 3

The rate of detectable (K^+, π^-, p) events from the $\Lambda = 0.012/\text{sec}/(dQ^2 \cdot dW) = 7200$ $/\text{week}/(dQ^2 \cdot dW)$. When this yield is divided among the $\theta^* - \phi^*$ and ϕ_e bins one finds about 300 counts/bin/week.

The rate of detectable (K^+, K^-, p) events from the $\Lambda^*(1520) = 0.009/\text{sec}/(dQ^2 \cdot dW)$ $= 5400$ $/\text{week}/(dQ^2 \cdot dW)$. When this yield is divided among the $\theta^* - \phi^*$ and ϕ_e bins one finds about 100 counts/bin/week.

The rate of detectable (K^+, K^-, p) events from the $f_0 = 0.0018/\text{sec}/(dQ^2 \cdot dW) =$ 1100 $/\text{week}/(dQ^2 \cdot dW)$. When this yield is divided among the $\theta^* - \phi^*$ and ϕ_e bins one finds about 20 counts/bin/week.

Based on the count rates estimated above, approximately 1000 hours of beam time would provide adequate statistics for a 10% determination of the density matrices for the most difficult case. This experiment could be run simultaneously with any other experiment which requires 3 or more particles in the final state since the rate of data surviving the Level 4 trigger is very small and there is the possibility of multiple triggers at Level 3.

Resources Required

1) The CLAS detector: a detector system capable of tracking at least three particles from the reactions discussed over a large angular range. Foward angle coverage (below 60°) is critical. Mass resolution in the various missing mass spectra must be sufficient to seperate Λ, Σ^0 and $\Lambda^*(1520)$ and particle identification must be sufficient to identify electrons, pions, kaons and protons.

2) Liquid hydrogen target. This must be suited for the large acceptance detector, i.e., something with thin walls and a mimimum of obstructions.

3) Trigger and computer system capable of selecting 3 and 4 particle final states from the host of other processes.

Manpower Requirements

The number of people in the CLAS collaboration is sufficient to build the detector and make the measurements.

References

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13. S. Abachi et al, Phys. Rev. Ltr. Vol 57, p1990 (1986)

Figure Captions

Fig. 1 The data above are from ref. 6.

(a) q^2 dependence for $\gamma_v p \to K^+\Lambda$. For comparision the curves corresponding to the total transverse cross section and a simple vector meson dominance prediction, both normalized to the photoproduction values, are given.

(b) q^2 dependence for the $\gamma_v p \to K^+\Lambda^*(1520)$. For comparison the curve corresponding to a simple vector meson dominance prediction, normalized to the photoproduction value, is given. This photoproduction value was obtained by extrapolating with $(W^2 - M_p^2)^{-2}$.

Fig. 2 GEANT simulation of a sample $e + p \to e' + K^+ + K^- + p$ event in which all four particles are predicted to be detected by the CLAS.

Fig. 3 CLAS acceptances for $e + p \to e' + K^+ + K^- + p$ for f_0, Λ and $\Lambda^*(1520)$ intermediate states. The solid, dashed and dotted lines in the lower left hand portion of the figure are the Q^2-W contours where the acceptance is approximately 3% for the f_0, Λ and $\Lambda^*(1520)$ intermediate states, respectively. The acceptance is greater than 3% above and to the right of these lines.

Fig. 4 Missing mass spectra for approximately 10^6 CELEG generated events and 3600 events each from Λ, and $\Lambda^*(1520)$. Only those events in which one electron and at least two other particles hit the scintillators were included in the figure.

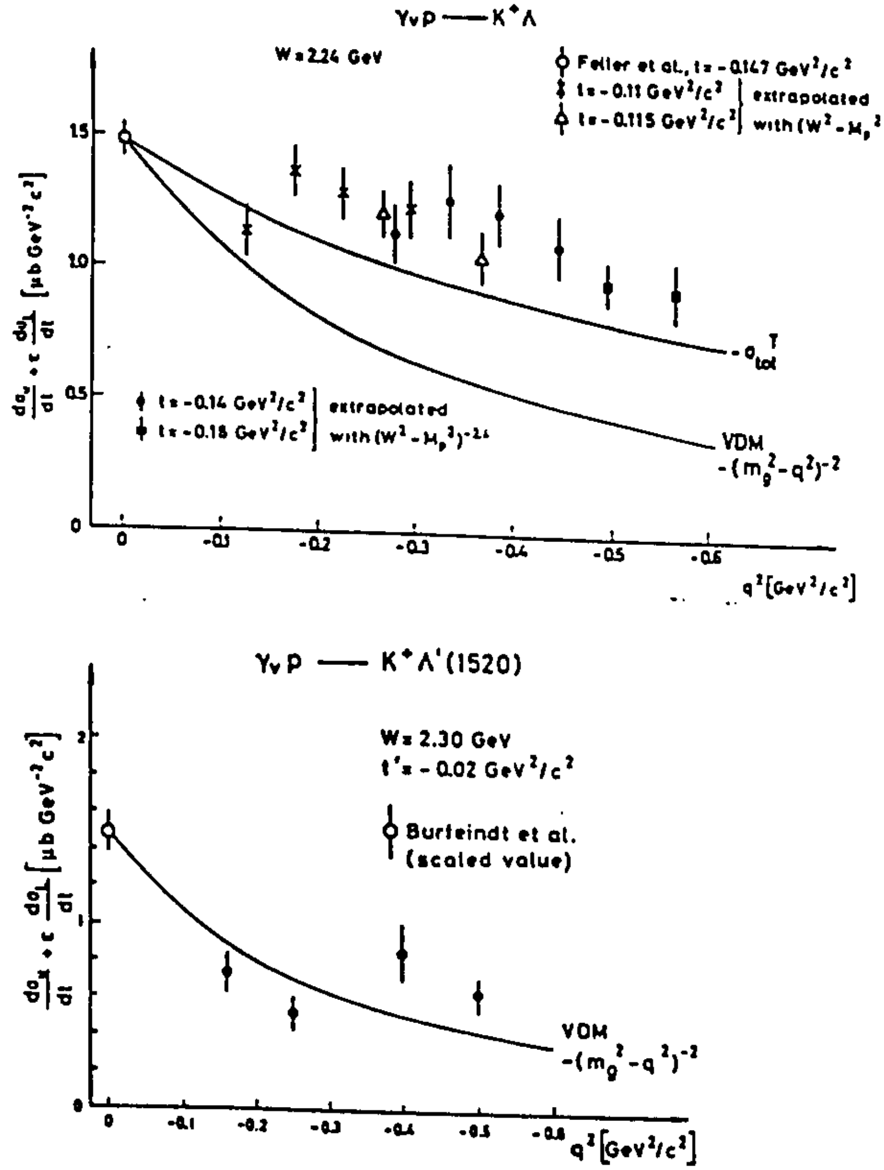
Fig. 5 (a) Distribution of the number of particles hitting the scintillators from the $e + p \to e' + K^+ + K^- + p$ and (b) from CELEG "background" events. The curve in (a) corresponds to events from $\Lambda^*(1520)$ production.

Fig. 6 Distribution of the types of coincidences observed from the $e+p \to e'+K^++K^-+p$ reaction. The shaded events represent those events which can be correctly reconstructed to obtain polarization information.

Fig. 7 Distribution of "experimentally" obtained masses (from FASTMC reconstructions) as a function of the actual mass.

Fig. 8 The time of flight vs momentum distribution obtained using FASTMC on modeled events.

Fig. 9 (a) TAC distribution for events of interest and (b) the "background" events generated by CELEG.



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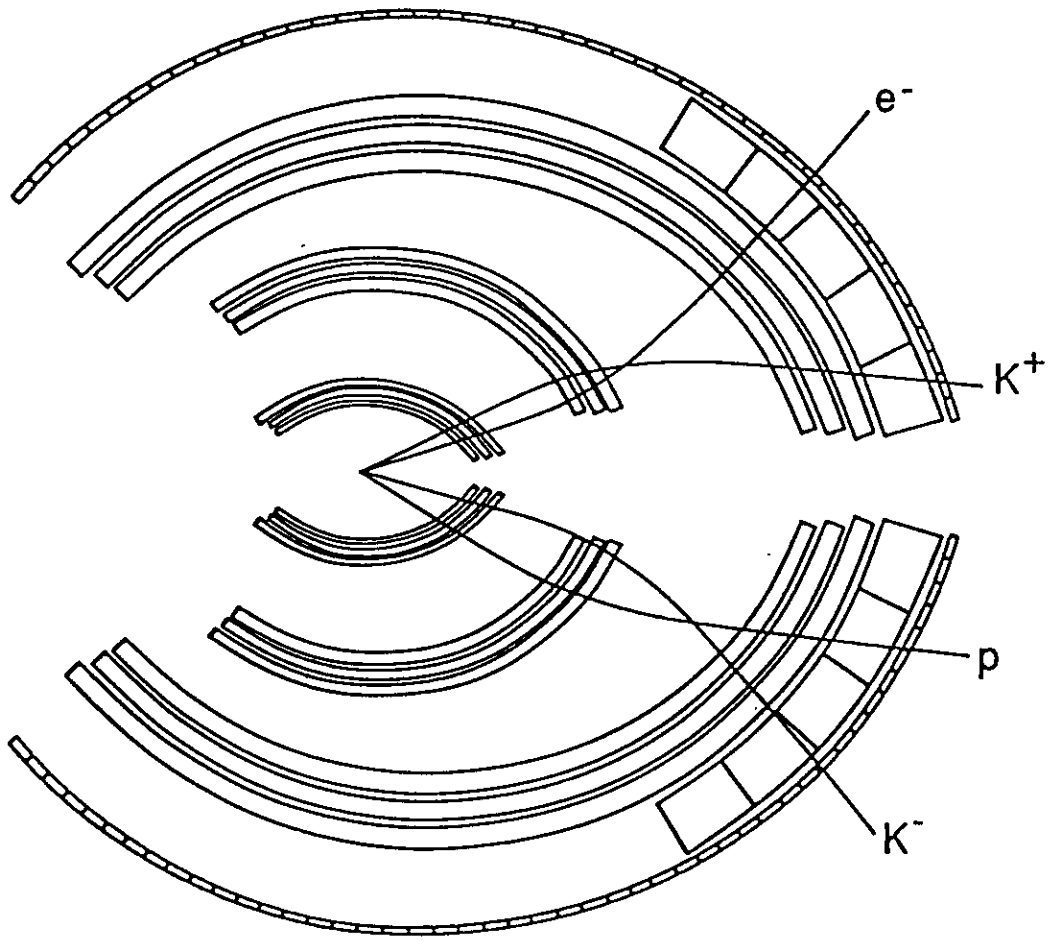

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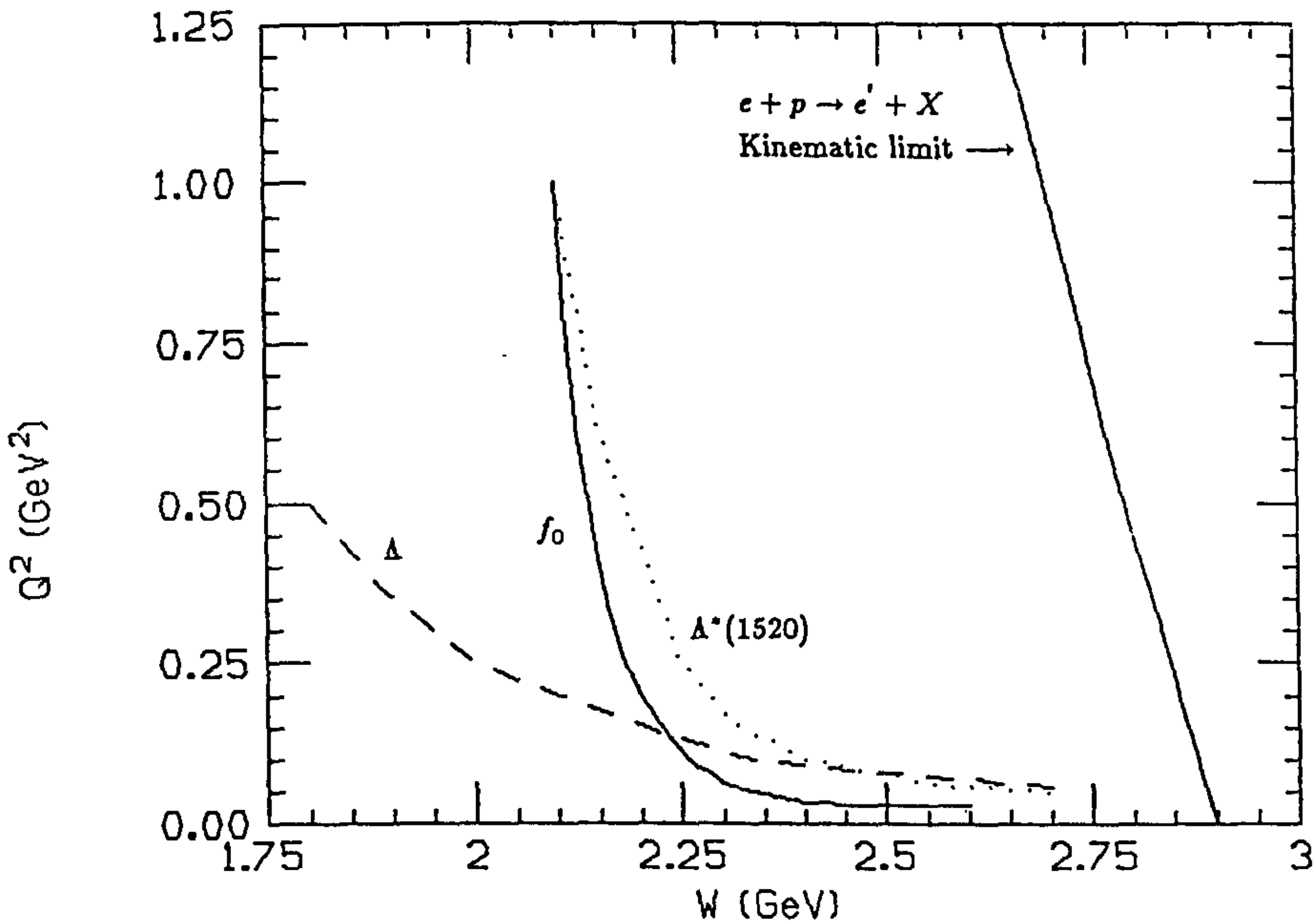

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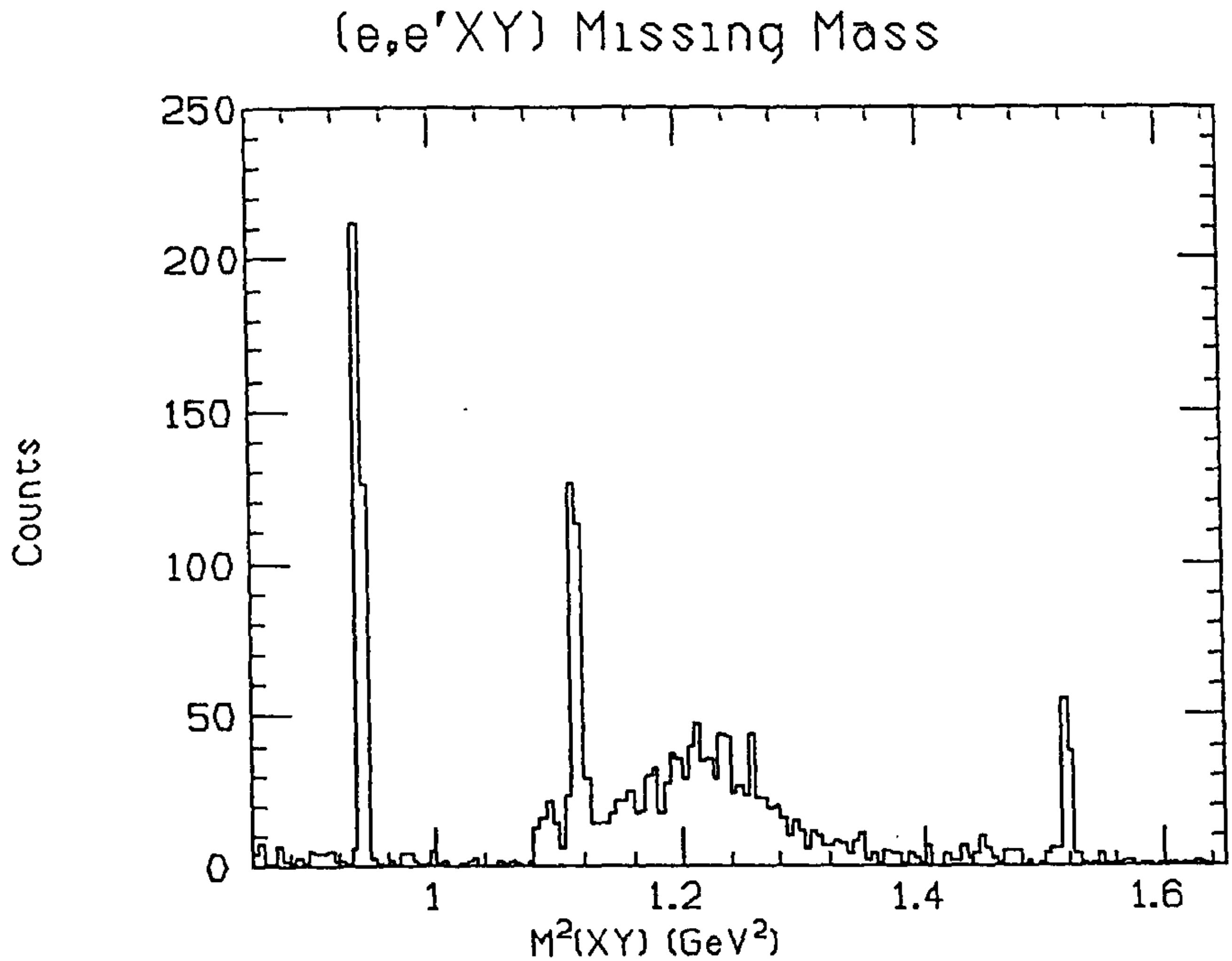

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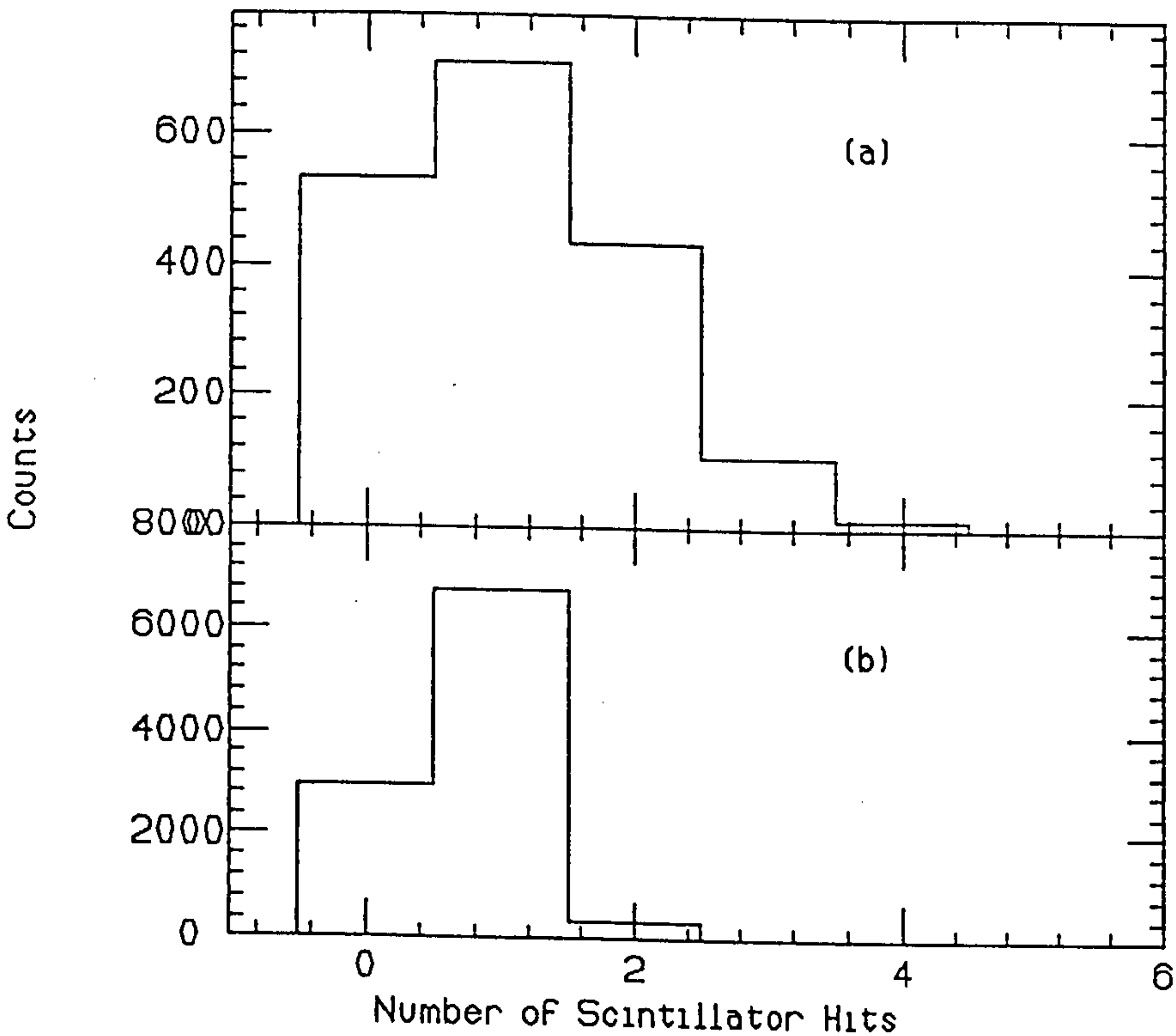


Fig. 5 (a) Distribution of the number of particles hitting the scintillators from the $e + p \rightarrow e' + K^+ + K^- + p$ and (b) from CELEG "background" events. The curve in (a) corresponds to events from $\Lambda^*(1520)$ production.

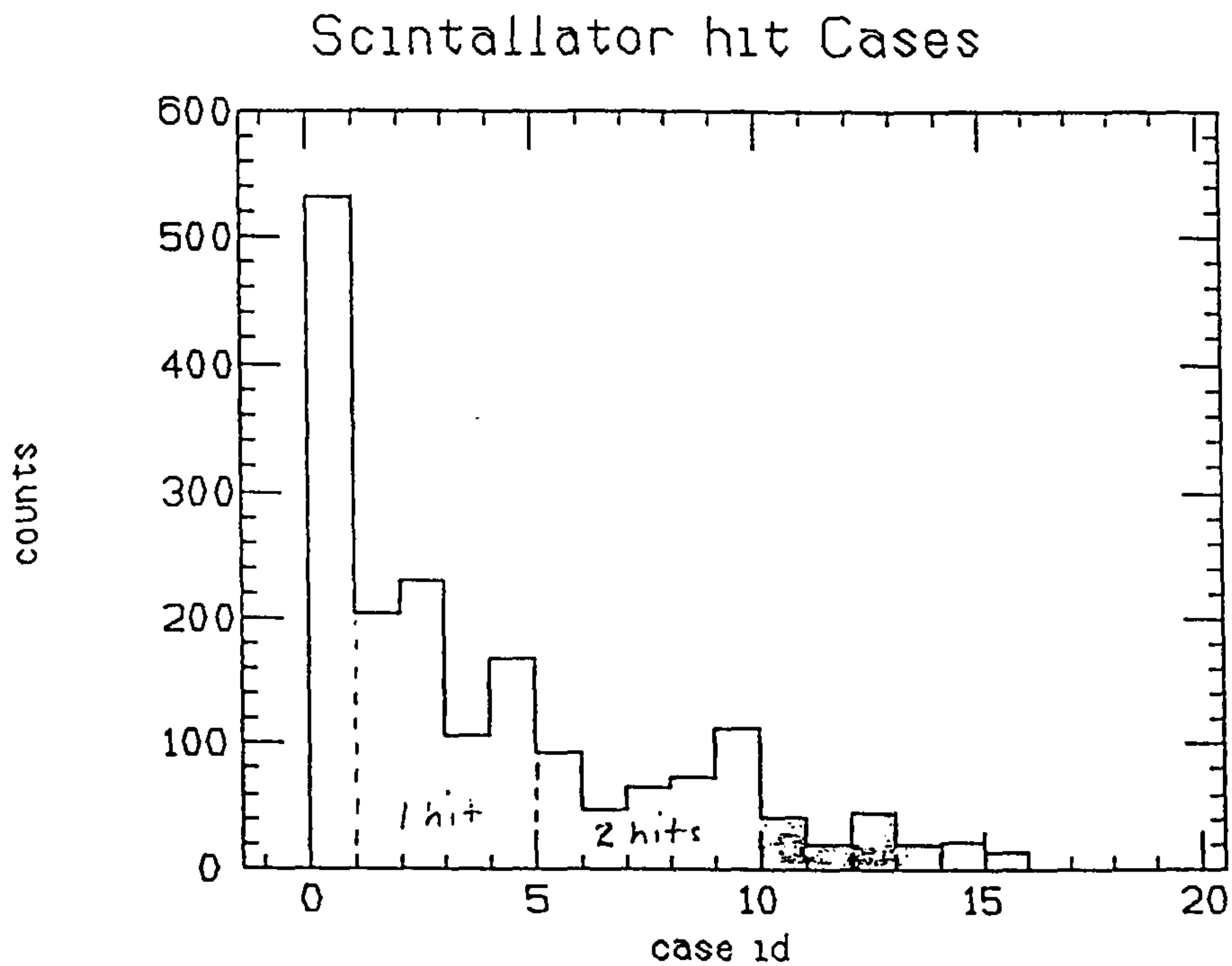


Fig. 6 Distribution of the types of coincidences observed from the $e + p \rightarrow e' + K^{+} + K^{-} + p$ reaction. The shaded events represent those events which can be correctly reconstructed to obtain polarization information.

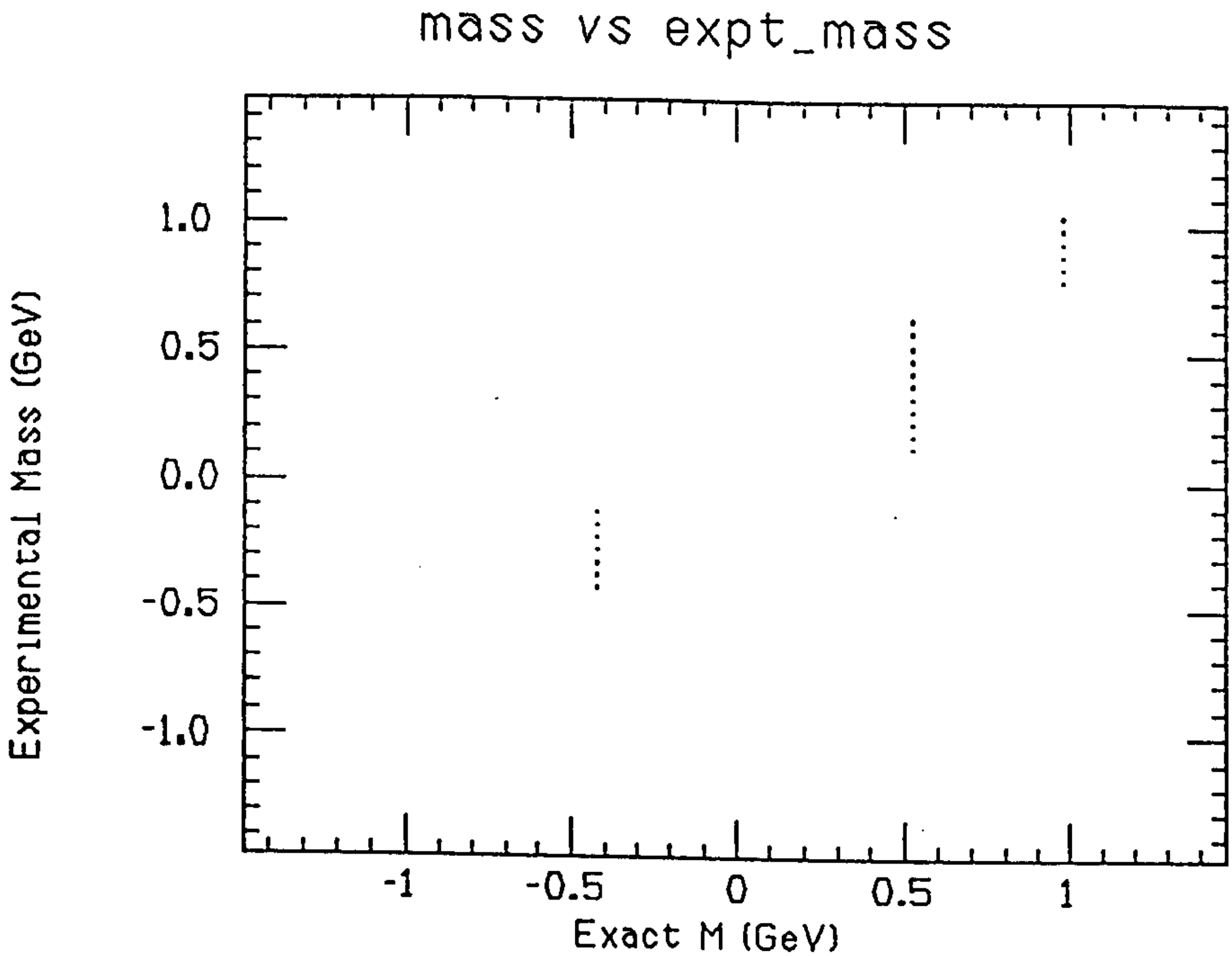


Fig. 7 Distribution of "experimentally" obtained masses (from FASTMC reconstructions) as a function of the actual mass.

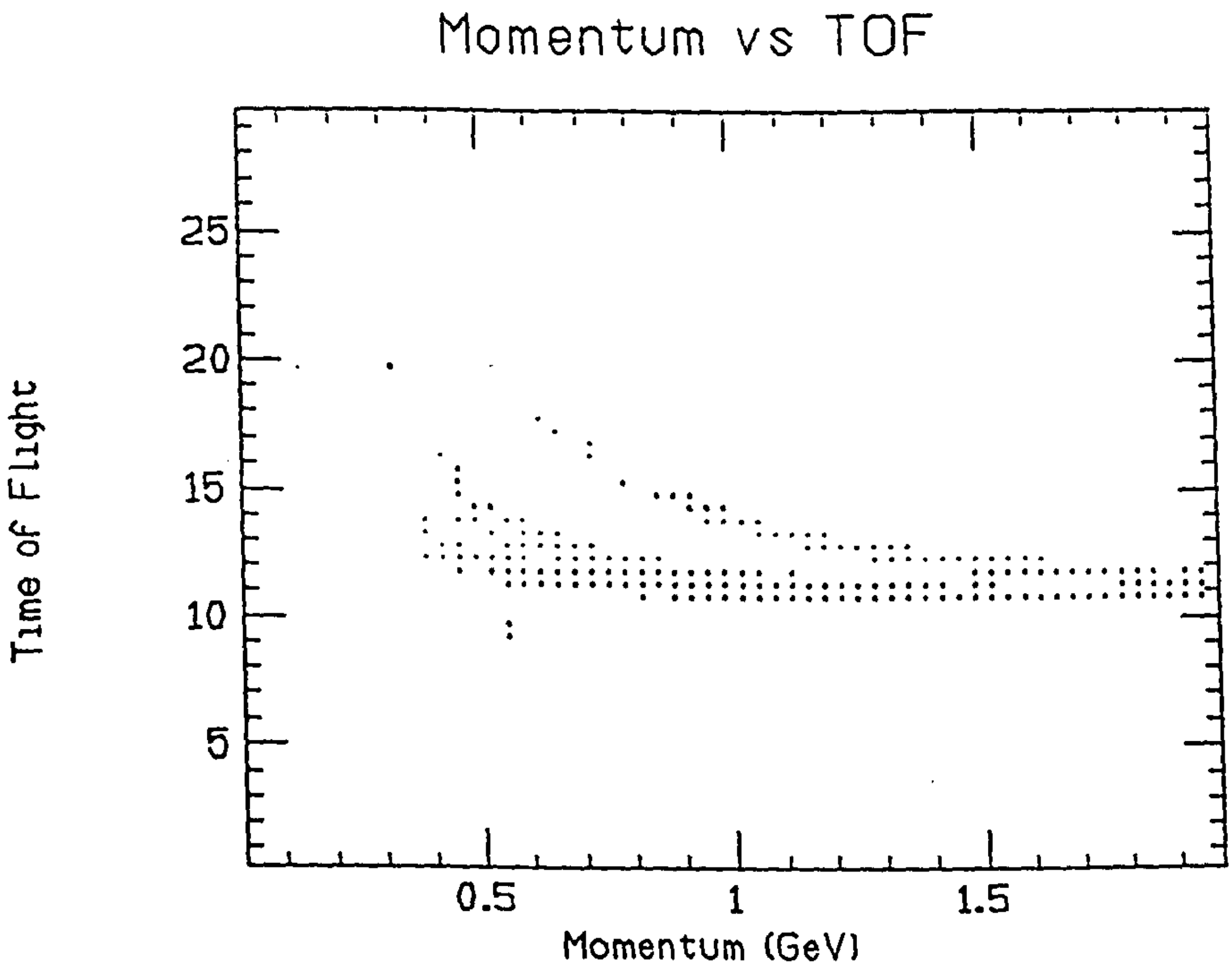


Fig. 8 The time of flight vs momentum distribution obtained using FASTMC on modeled events.

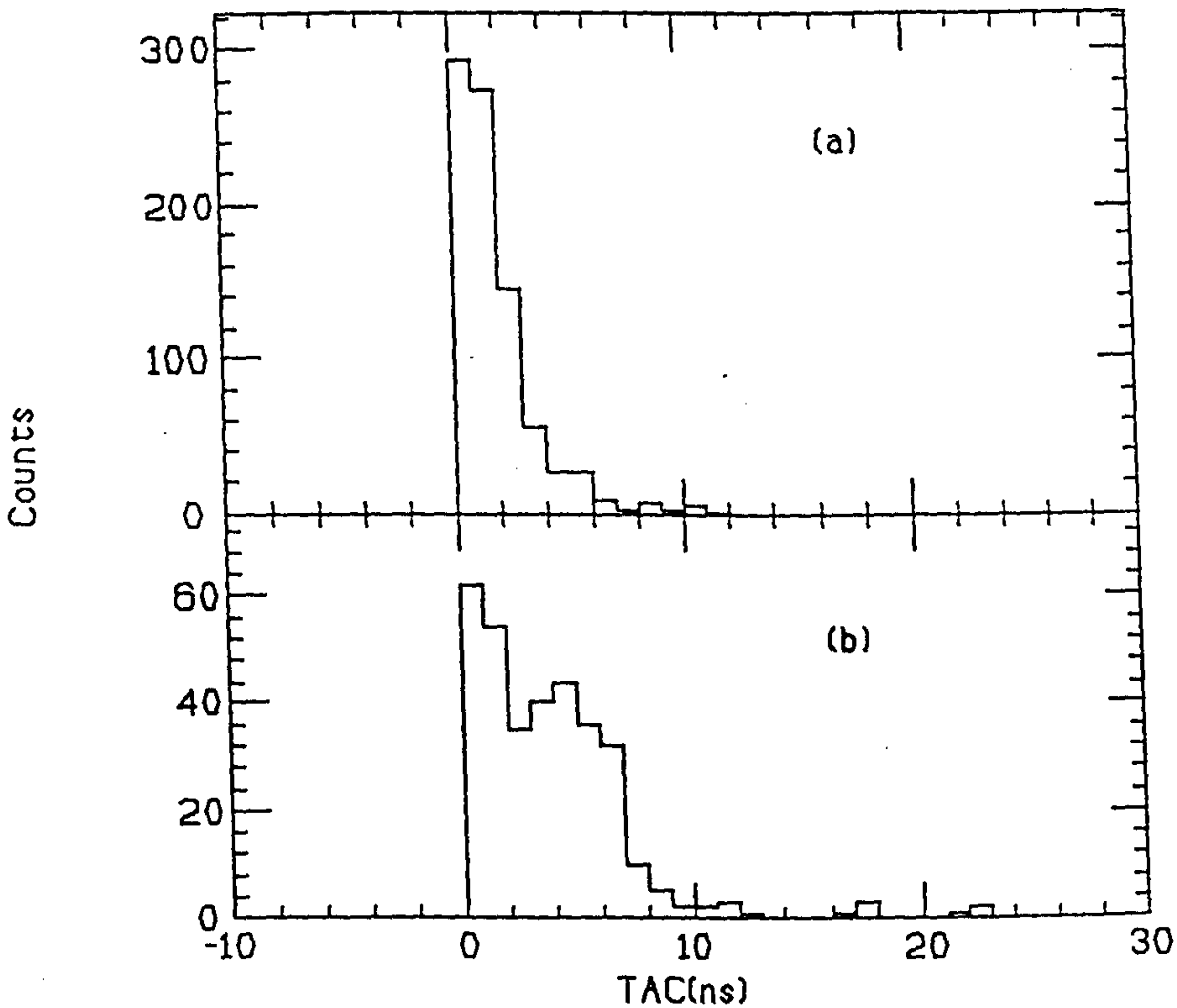
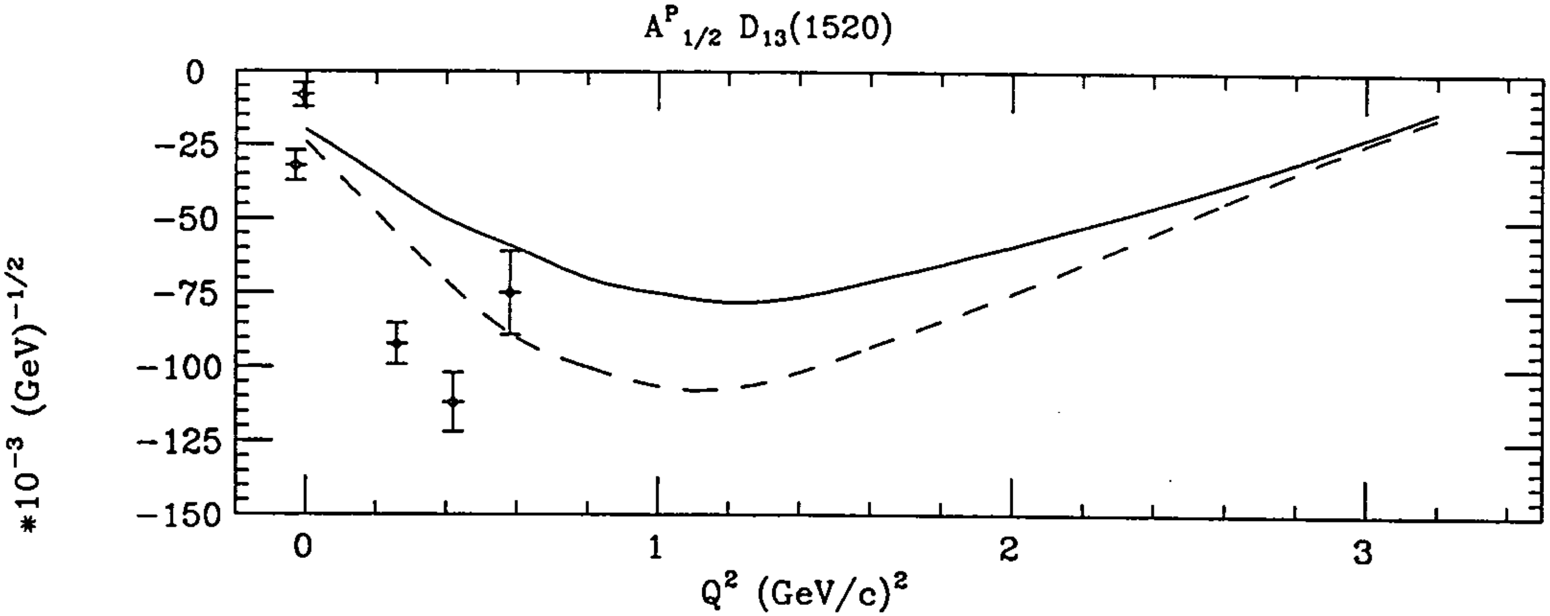
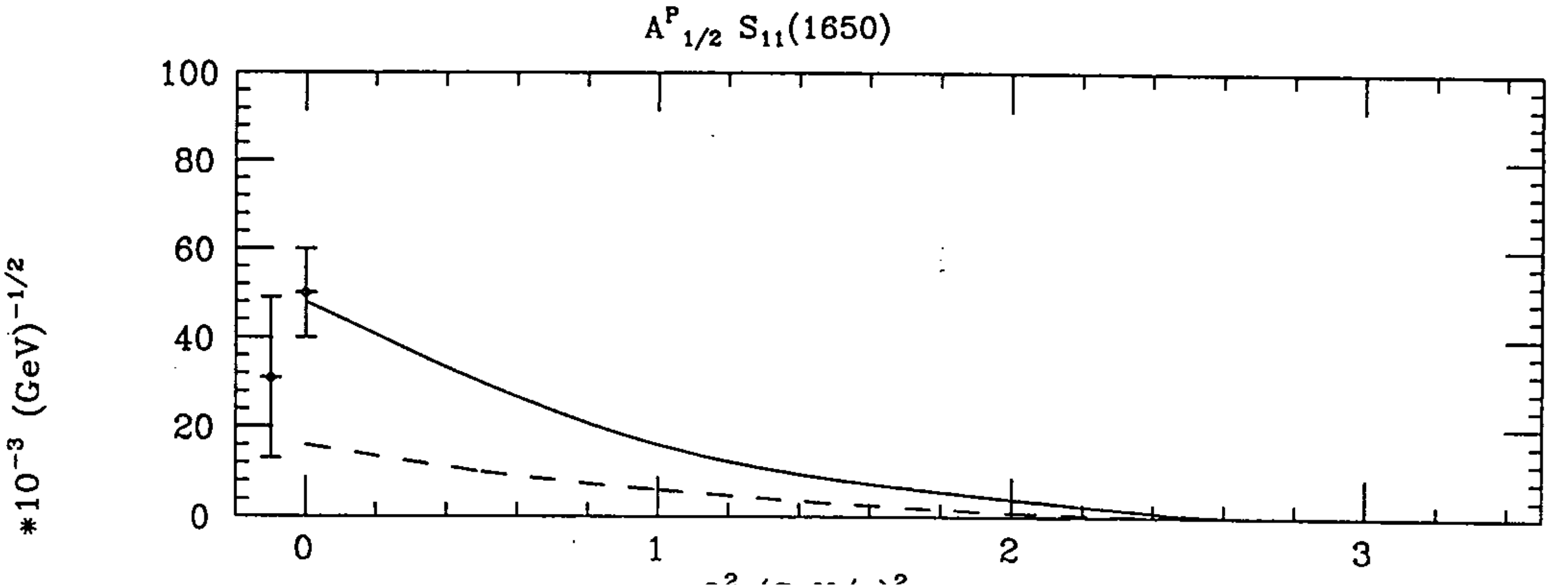
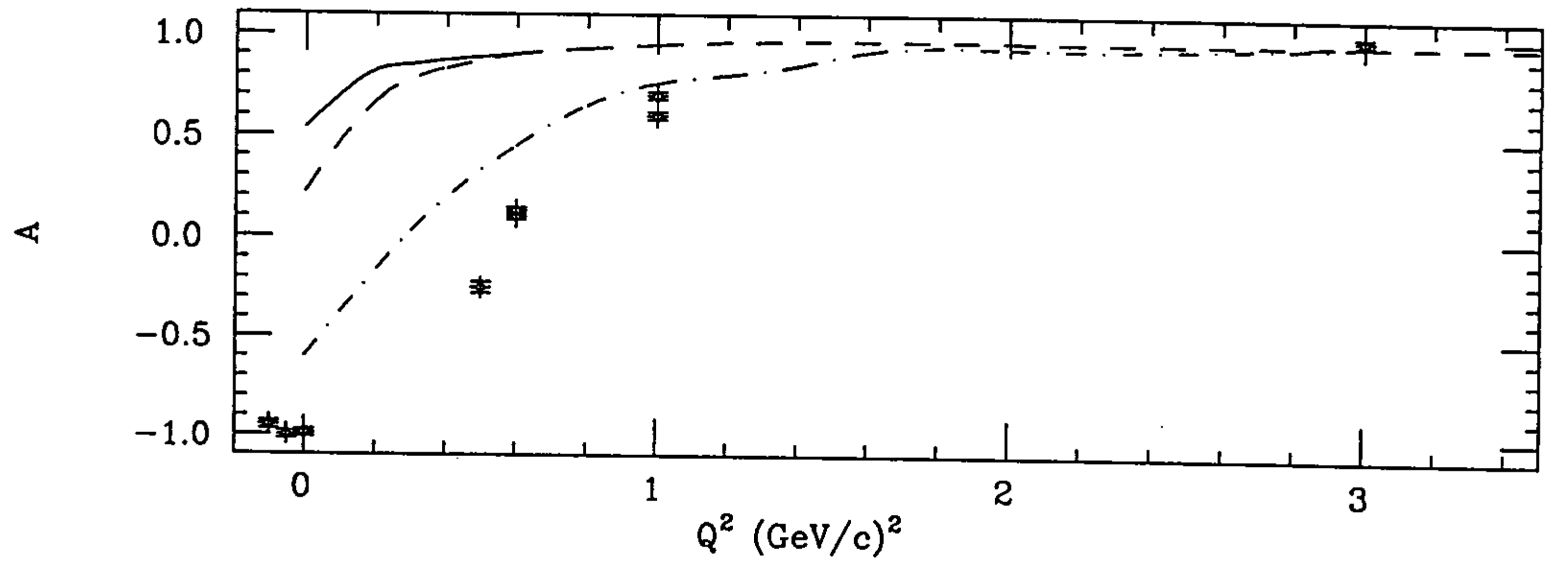


Fig. 9 (a) TAC distribution for events of interest and (b) the "background" events generated by CELEG.


A^P 1/2 D13(1520)
*10^-3 (GeV)^-1/2
0
-25
-50
-75
-100
-125
-150
0
1
2
3
Q^2 (GeV/c)^2


A^P 1/2 S11(1650)
*10^-3 (GeV)^-1/2
100
80
60
40
20
0
0
1
2
3

$D_{13}(1520)$ Helicity Asymmetry



$F_{15}(1690)$ Helicity Asymmetry