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EVIDENCE FOR A NARROW K_N^* RESONANCE AT 1250 MeV*

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ABSTRACT

We present evidence for the existence of a $K_N^*(1250)$ resonance of mass $M = 1247\pm5$ MeV and width $\Gamma = 20^{+9}_{-6}$ MeV, seen in the reaction $K^+n \rightarrow K^+\pi^-p$ at 12 GeV/c. The resonance is most probably produced by pseudoscalar exchange, and its spin parity is either $J^P = 0^+$ or $J^P = 1^-$.

We have studied the reaction $K^+n \rightarrow K^+\pi^-p$ in a 12-GeV/c K^+-deuterium experiment in the SLAC 82-inch bubble chamber. In addition to the well-established $K^*(890)$ and $K^*(1420)$ resonances, we observe a narrow K_N^* (N refers to normal spin parity) resonance at $M = 1247\pm5$ MeV and $\Gamma = 20^{+9}_{-6}$ MeV. This resonance is produced primarily in the low momentum transfer region most probably via pseudoscalar exchange, and its spin parity is either $J^P = 0^+$ or $J^P = 1^-$. A K^* resonance at this mass has been reported in a compilation by W. P. Dodd et al.[1]; however, their quoted width is 70 MeV, which is significantly broader than the width observed in this experiment. In addition, at large momentum transfers, we also observe some structure in the region $1 \text{ GeV} < M(K^+\pi^-) < 1.2$ GeV. Evidence for two enhancements in this region have been reported: a $K^*(1080)$ (Ref. 2) and a $K^*(1160)$ (Ref. 3). However, the statistical significance of any peaks in that region is marginal in the sample analyzed to date in this experiment.

The SLAC 82-inch bubble chamber was exposed to an rf-separated 12-GeV/c K^+ meson beam. Resolution in the beam momentum to within $\Delta p/p = \pm 0.2\%$ is achieved by using the known correlation between beam momentum and transverse position in the bubble chamber.[4] Through the use of a gas Čerenkov counter, pion contamination in the beam is reduced essentially to zero. On the average eight K^+ mesons were incident in the chamber per pulse. The bubble chamber was filled with deuterium, but there was a hydrogen contamination of 4.5%. Approximately 500 000 exposures were taken, of which about 60% have been analyzed to date. The experimental details have been reported previously[5] in a study of the elastic charge exchange reaction $K^+n \rightarrow K^0p$. In the present work we report on the charge exchange reaction $K^+n \rightarrow K^+\pi^-p$.

The film has been scanned for all events which have three-prong or four-prong topologies. In addition, all measured four-prongs were required to have at least one track which stops in the bubble chamber. The events were measured on the LRL Flying-Spot Digitizer, and were reconstructed and kinematically fitted in the program SIOUX. For those events with invisible spectators (three-prongs), the spectator was assigned a momentum of zero with errors $\Delta p_x = \Delta p_y = \pm 30$ MeV/c, and $\Delta p_z = \pm 40$ MeV/c. All events of both topologies which fit the four-constraint hypothesis, $K^+d \rightarrow K^+\pi^-pp$, with χ^2 probability greater than 0.1% were accepted as this hypothesis.

In the reaction $K^+d \rightarrow K^+\pi^-pp$, it is assumed that the slower proton in the laboratory system is the spectator and the faster proton is the recoiling particle. If this choice is made, then the slower proton has a momentum distribution in agreement with that expected from the Hulthèn wave function for momenta less than 300 MeV/c. For the subsequent analysis only events with $p_{spect} < 300$ MeV/c are accepted. There are 4260 such events, of which 67% are three-prongs and 33% are four-prongs.

The total cross section for the reaction $K^+n \to K^+\pi^-p$ has been calculated to be 399±8 μb. This cross section has been determined by normalization to the well-known K^+d total cross section at 12 GeV/c, and has been corrected for the following effects: (1) the topological dependence of scanning efficiencies, (2) measurement efficiencies, (3) hydrogen contamination in the bubble chamber, and (4) the suppression of events in the very small momentum transfer region due to the Pauli exclusion principle in the final state. No correction has been made for the Glauber-Wilkin screening effect which is expected to be small. The quoted error reflects statistical uncertainties only.

Figure 1 shows the Dalitz plot for the reaction $K^+n \to K^+\pi^-p$. The outstanding features of this plot include the following: (1) a large low-mass enhancement in the $p\pi^-$ system, which is associated with several N^* resonances, (2) a $K^*(890)$ band, (3) a $K^*(1420)$ band, (4) a striking depletion of events in a band with $M^2(K^+\pi^-) \sim 2.4\ \text{GeV}^2$, (5) an excess of events asymmetrically distributed along a band with $M^2(K^+\pi^-) \sim 3\ \text{GeV}^2$, and (6) a general lack of background events. The Particle Data Tables list seven $N^*_{1/2}$ resonances with masses less than 1.8 GeV,[6] several of which could contribute to the low-mass enhancement in the $p\pi^-$ distribution. Except possibly for some structure at $M^2(p\pi^-) \sim 2\ \text{GeV}^2$, which is probably associated with the P_{11} Roper resonance, none of them can be resolved without cuts in momentum transfer. The Dalitz plot shows that, although there is perhaps some $K^*(1420)N^*$ and $K^*(890)N^*$ constructive interference, the N^* band is not continuous. The depletion of events in a band with $M^2(K^+\pi^-) \sim 2.4\ \text{GeV}^2$ cuts right across the N^* band, and in addition the N^* band does not persist down to the region between the $K^*(890)$ and $K^*(1420)$. Moreover, the well-known asymmetry in the $K^*(890)$ decay angular distribution, which appears on the Dalitz plot as an asymmetric population density along the $K^*(890)$ band, appears not to be associated with the N^*; i.e., the high density region of the $K^*(890)$ band is roughly the region with $M^2(p\pi^-) < 7\ \text{GeV}^2$, whereas the region attributable to the N^* is only the region with $M^2(p\pi^-) < 3\ \text{GeV}^2$.

Figure 2a shows the mass distribution $M(K^+\pi^-)$ for all the events in the sample. In addition to the features noted already, there is a sharp spike at a mass of $M(K^+\pi^-) = 1250$ MeV. Figure 2b shows the data with the N^* peak removed [$M(p\pi^-) \geq 1.8$ GeV] and the low t region selected [$t_{K\to K\pi} < 0.2\ (\text{GeV}/c)^2$]. The enhancement is about 5 standard deviations above background in this distribution. A fit to the data of a Breit-Wigner line shape gives the following values for the parameters of this $K^*(1250)$ resonance, $M = 1247 \pm 5$ MeV and $\Gamma = 20^{+9}_{-6}$ MeV, with a $\chi^2 = 3.95$ for six degrees of freedom. The results of this fit are shown as the smooth curve in Fig. 2c. The parameters quoted have not been corrected for resolution. In a compilation by W. P. Dodd et al.,[1] a K^* resonance at approximately this mass was observed; however, the width reported in that case was 70 MeV. If the large t region is selected, i.e., $t_{K\to K\pi} > 0.2\ (\text{GeV}/c)^2$, the $K^*(1250)$ does not appear significantly above the background, but there is some evidence for structure in the region $1\ \text{GeV} < M(K^+\pi^-) < 1.2$ GeV. Evidence for two enhancements have been reported in this region; a $K^*(1080)$ (Ref. 2) and a $K^*(1160)$ (Ref. 3). However the statistical significance of any peaks in this region is marginal in the sample analyzed to date in this experiment.

Figure 3 shows the decay angular distributions, $\cos\theta$ and φ, and the distribution in momentum transfer, $t_{K\to K\pi}$ for the region of the $K^*(1250)$ and for two neighboring regions. The region of the $K^*(1250)$ has been defined as the 40-MeV band, 1.19-1.23 GeV (see Fig. 2c). The neighboring regions have also been taken as 40-MeV wide on either side of the $K^*(1250)$ region. The angle θ is the angle between the incident K^+ and the outgoing K^+ in the $K^+\pi^-$ rest frame (Jackson angle), and the angle φ is the azimuth of the outgoing K^+ about the incident K^+ axis in the $K^+\pi^-$ rest frame (Treiman-Yang angle). No cuts have been made in this data except for the indicated mass cut; specifically, $M(p\pi^-) > 1.8$ GeV has not been selected here, because such a selection is equivalent to a cut on θ, i.e., a cutting out of forward K^+ ($\cos\theta \sim +1$) events.

In the $K^*(1250)$ region, the distribution is consistent either with isotropy or with a polynomial in $\cos\theta$ of order 2. There is no evidence for any term in $\cos^n\theta$ where $n > 2$. We have fit the data to a function of the form $a_o + a_1P_1(\cos\theta) + a_2P_2(\cos\theta)$, where the $P_i(\cos\theta)$ are the Legendre polynomials in $\cos\theta$. We obtain a $\chi^2 = 22.9$ for 17 degrees of freedom, and the best fit normalized parameters are $(a_1/a_o) = 0.28\pm0.19$ and $(a_2/a_o) = 0.86\pm0.22$. In the region below the $K^*(1250)$ there is no evidence for any deviation from isotropy, and in fact in that region we obtain parameters $(a_1/a_o) = 0.31\pm0.23$ and $(a_2/a_o) = -0.11\pm0.29$, but a fit to an isotropic distribution ($a_1 = a_2 = 0$) yields a $\chi^2 = 11.8$ for 19 degrees of freedom. In the region above the $K^*(1250)$ the data are consistent with isotropy, but there is some evidence for an asymmetry in this region; however this may be due to the effects of the tail of the $K^*(1420)$ which is becoming important at 1.3 GeV. The best fit parameters in this region are $(a_1/a_o) = 0.62\pm0.21$ and $(a_2/a_o) = 0.41\pm0.20$.

A least squares fit to the t distribution in the $K^*(1250)$ region (Fig. 3h) yields a slope of 12.5 ± 1.5 $(\text{GeV}/c)^{-2}$, which is certainly consistent with slopes generally observed for pion exchange processes. If the $K^*(1250)$ is in fact produced primarily by pion exchange, then we may say that its spin-parity must be either $J^P = 0^+$ or 1^-, as there is no evidence for any terms higher than

$\cos^2\theta$ in the decay angular distribution. At the present level of statistics we cannot distinguish between $J^P = 0^+$ and $J^P = 1^-$, but the value of (a_2/a_0) in the $K^*(1250)$ region tends to favor the $J^P = 1^-$ interpretation as this parameter would be zero for a $J^P = 0^+$ resonance produced by pion exchange. However, in the present sample we cannot determine to what extent the deviation of the parameter from zero is due to background effects.

We have also investigated the charge exchange reaction $K^+n \rightarrow K^o\pi^+\pi^-p$, in which the K^o decays visibly in the bubble chamber. In the $K^o\pi^+\pi^-$ mass distribution there is no evidence for any signal below the $K^*(1420)$. The Q is not produced in this charge exchange reaction and neither is the $K^*(1250)$. The absence of a three-body decay mode for the $K^*(1250)$ indicates that it is not associated with the structure in the Q at about this mass.[7]

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FIGURE CAPTIONS

Fig. 1. Dalitz plot $M^2(p\pi^-)$ vs $M^2(K^+\pi^-)$ for the reaction $K^+n \to K^+\pi^-p$.

Fig. 2. $M(K^+\pi^-)$ for the reaction $K^+n \to K^+\pi^-p$ with (a) no cuts, (b) $M(p\pi^-) > 1.8$ GeV and $t_{K\to K\pi} < 0.2\ (\text{GeV}/c)^2$, and (c) same as (b) in 10-MeV bins. The smooth curve in (c) is the result of a fit to a Breit-Wigner shape. See text.

Fig. 3. (a) $\cos\theta$, the $K\pi$ decay angle, (b) φ, the Treiman-Yang angle, and (c) $t_{K\to K\pi}$ in three mass regions: (i) below the $K^*(1250)$, (ii) in the $K^*(1250)$, and (iii) above the $K^*(1250)$.

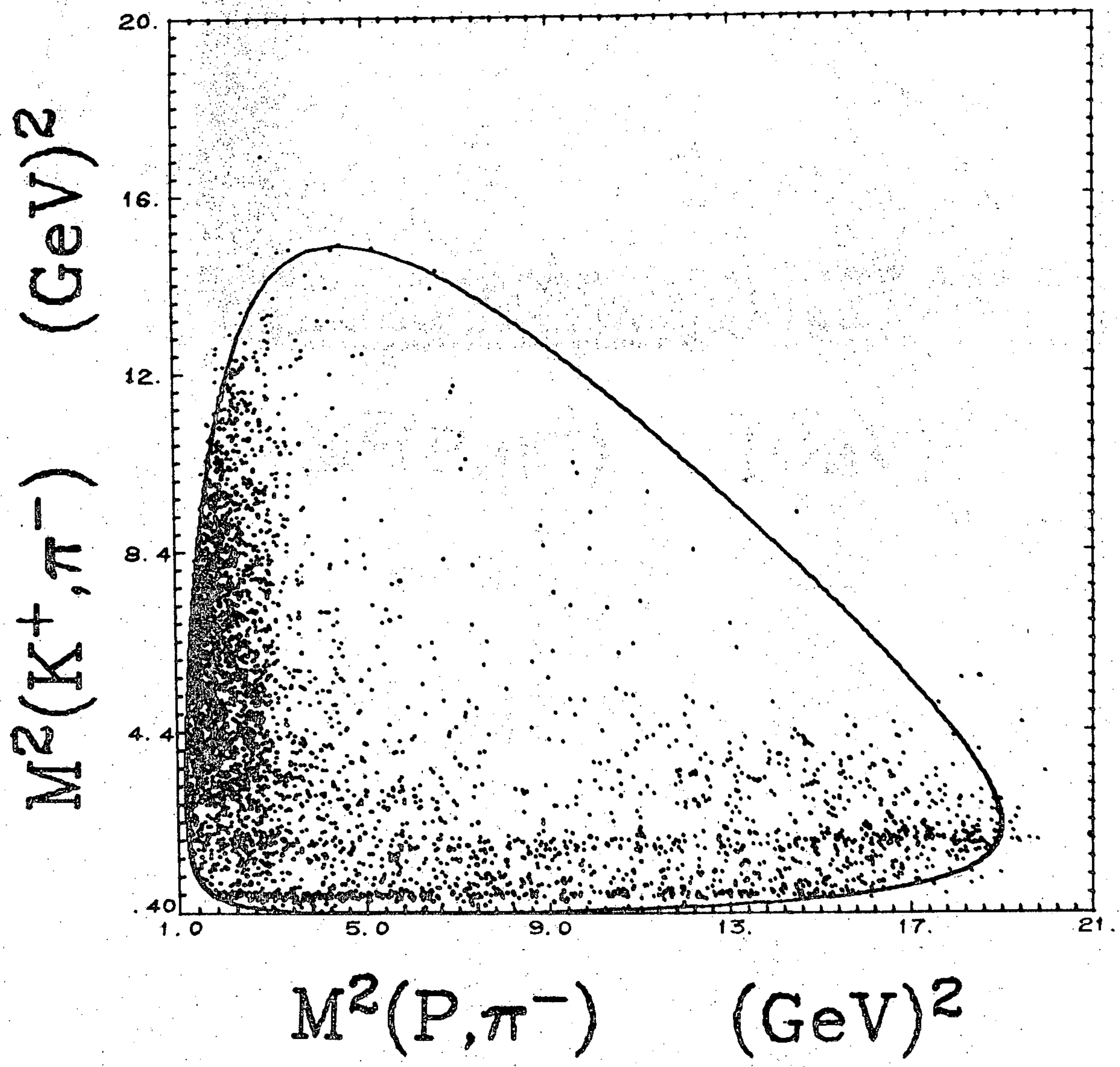

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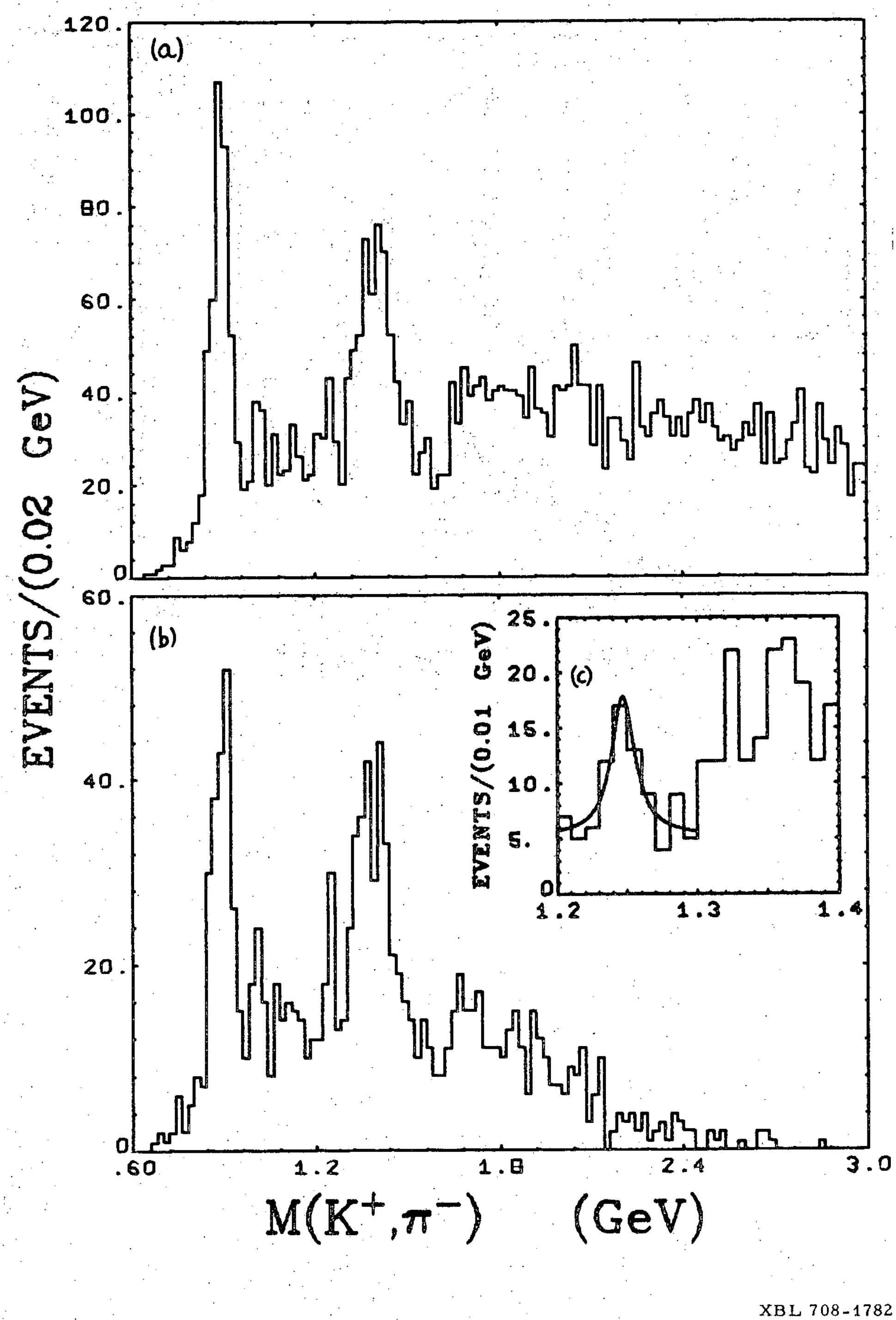
Fig. 1



120.
100.
80.
60.
40.
20.
0
(a)
60.
40.
20.
0
(b)
EVENTS/(0.02 GeV)
25.
20.
15.
10.
5.
0
(c)
EVENTS/(0.01 GeV)
1.2
1.3
1.4
.60
1.2
1.8
2.4
3.0
M(K+,π−) (GeV)
XBL 708-1782

Fig. 2

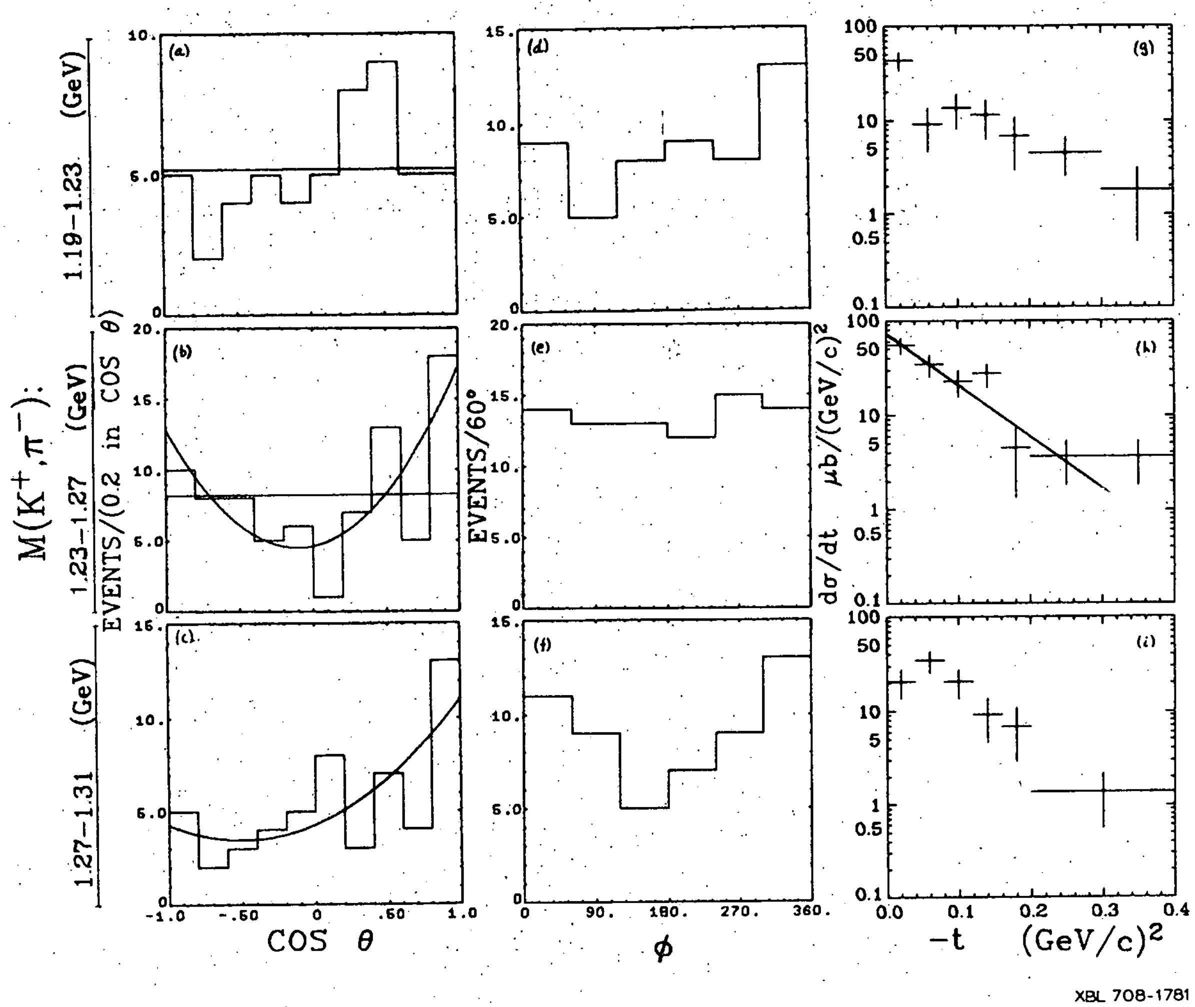

M(K+,π−):
1.19−1.23 (GeV)
1.23−1.27 (GeV)
1.27−1.31 (GeV)
EVENTS/(0.2 in COS θ)
EVENTS/60°
dσ/dt μb/(GeV/c)²
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
COS θ
φ
−t (GeV/c)²
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Fig. 3

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