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SEARCH FOR GLUEBALLS AT HIGH p_T IN 300 GeV/c π^-N INTERACTIONS

Athens[1]-Bari[2]-Birmingham[3]-CERN[4]-Paris (Collège de France)[5]-
Paris (LPNHE)[6] Collaboration

M. Benayoun[5], W. Beusch[4], I.J. Bloodworth[3], J.N. Carney[3], R. Fini[2], B.R. French[4], B. Ghidini[2], Y. Goldschmidt-Clermont[4], G. Ingelman[4(*)], A. Jacholkowski[4], J. Kahane[5], J.B. Kinson[3], K. Knudson[4], V. Lenti[2], Ph. Leruste[5], A. Malamant[5], W. Mitaroff[4(**)], J.L. Narjoux[5], F. Navach[2], R. Petronzio[4(***)], I.C. Print[3], E. Quercigh[4], M. Sené[6], R. Sené[5], H.R. Shaylor[3], M. Stassinaki[1], Z. Strachman[6], M.T. Trainor[3], G. Vassiliadis[1], O. Villalobos Baillie[3], M.F. Votruba[3], G. Zito[2] and R. Zitoun[6]

(1) Nuclear Physics Department, Athens University, Athens, Greece
(2) Dipartimento di Fisica dell'Università and Sezione INFN, Bari, Italy
(3) Physics Department, University of Birmingham, Birmingham, UK
(4) CERN, European Organisation for Nuclear Research, Geneva, Switzerland
(5) Laboratoire de Physique Corpusculaire, Collège de France, Paris, France
(6) LPNHE, Universités de Paris VI et VII, Paris, France

ABSTRACT

The production of glueball candidates ι and Θ in hadronic interactions is investigated at high transverse momenta. The data come from a sample of π^-N interactions at 300 GeV/c obtained at the CERN Omega Spectrometer, using a trigger and off-line selection requiring a system of charged particles with $p_T > 2$ GeV/c recoiling against an opposite particle with $p_T > 0.9$ GeV/c. Cross sections are given for known resonances (ρ^o, ϕ, f^o) and upper limits for the $\iota(1440)$ and $\theta(1720)$. A comparison is made with recent theoretical calculations.

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(*) Now at DESY, Hamburg.
(**) Now at Institute für Hochenergie Physik, Wien.
(***) Now at Max Planck Institute, Munich.

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The glueballs or gluonia, first suggested by Fritzsch and Gell-Mann, are flavourless unstable mesons composed mainly of glue whose existence appears to be a consequence of Quantum ChromoDynamics (QCD), so long as colour is confined.

The search for these new states has been carried out in several experiments and has led to the observation of a number of candidates. Firm evidence for the glueball nature of these signals is however still lacking, the main difficulty being how to distinguish a glueball from an ordinary $q\bar{q}$ meson. It is clearly of interest to study a range of processes where one can expect production of these states to be favoured, as the observation of any of the candidates in such new processes would strengthen its interpretation as gluonium.

Experiment WA77 [1] is intended to study high p_T hadroproduction of meson states. This is of interest because recent calculations [2] indicate that direct high p_T meson production via higher twist QCD mechanisms, as shown in fig. 1(a,b), could be an important source of both quarkonia and gluonia; it has also been suggested that gluonium states could be formed at high p_T in the fragmentation of gluon jets [3]. In this paper we present the results of a search for the glueball candidates $\iota(1440)$, $(\eta(1440))$ [4] and $\theta(1720)$, $(f_2(1720))$ [5] seen in radiative J/ψ decays. We also give cross sections for the high p_T production of the $\rho^o(770)$, $f^o(1270)$, $(f_2(1270))$ and $\phi(1020)$ resonances.

In direct production a meson is formed in the parton collision via QCD higher twist processes [2]. The WA77 trigger has been designed to enhance direct meson production signals, making use of the feature that a directly produced meson picks up the full momentum transfer carried by the exchange (fig. 1(a,b)), while in "indirect" production, via parton scattering and subsequent fragmentation, the momentum transfer is shared amongst the fragmentation products. We want to search for events in which a meson resonance decaying into two or more particles recoils against one high p_T particle. In order to do this, the trigger selects events with three high p_T charged particles ($p_T > 0.9$ GeV/c) and c.m.s. rapidities in the range $-1 \leq Y^* \leq 1$; i.e. a pair of oppositely charged particles is required to be opposite in azimuth to a third one (fig. 1(c,d)). Details concerning the apparatus and the event reconstruction have been given in previous publications [6,7].

First, we consider high p_T production of the $\theta(1720)$. Here we are looking for a resonance decaying into two oppositely charged (triggering) particles with a charged particle (also triggering) as the leading particle on the opposite side (fig. 1(c)). The selections made are given below:

$$\begin{aligned} &p_T \text{ (pair)} > 2 \text{ GeV/c}, \quad p_T \text{ (opposite)} > 1 \text{ GeV/c}, \\ &p_T \text{ (pair)} > p_T \text{ (opposite)}, \qquad \text{Selection (1)} \\ &-0.45 < Y^* \text{ (pair, assumed } \pi^+\pi^-) < 0.45, \end{aligned}$$

and give a data sample of 266611 events.

The invariant mass spectrum for the pairs of high p_T particles, as defined above, assuming both particles in the pair to be pions, is shown in fig. 2(a). Clear signals are present in the $\rho^0(770)$ and $f^0(1270)$ mass regions. The curves are the result of fits described in ref. [6].

Turning to the K^+K^- mass assignment, which is shown in fig. 2(b), a clear signal is seen in the $\phi(1020)$ region. The mass spectra also show enhancements due to reflections of resonance decays where inappropriate mass assignments have been made (e.g. K^*, ρ^0, f^0 reflections). The shaded region in fig. 2(b) shows the K^+K^- mass spectrum where at least one particle in the pair has been identified as a kaon in the Cherenkov counters. As expected the reflections are suppressed. No structure is seen in the θ region in either fig. 2(a) or fig. 2(b).

Cross sections for high p_T production ($p_T > 2$ GeV/c), where the recoil included one charged particle with $p_T > 1$ GeV/c, selection (1), have been determined for the ρ^0, f^0 and ϕ taking into account the measurement detection efficiencies of the trigger and associated electronics, the efficiency of the spectrometer and of the track reconstruction program, and the geometrical acceptance of the apparatus. The acceptance, evaluated by a Monte-Carlo procedure, is to some extent model-dependent. We have assumed isotropic angular distributions for resonance decays throughout this paper. The cross sections obtained are given in table 1(a).

A 95% confidence level upper limit of 265 events for the θ is obtained from fig. 2(b) in the mass interval $1.649 < M(K^+K^-) < 1.783$ GeV correspond-

ing to a one Γ interval about the Θ mass. This gives an upper limit on the cross section for $\Theta(1720) \to K^+K^-$ of 0.03 μb as given in table 1(b).

In order to search for the ι(1440) we consider the $K_s^o K^\pm \pi^\mp$ system produced at high p_T. We use events with two reconstructed vertices and three trigger tracks as shown in fig. 1(d). We require that one of the triggering tracks for the $K_s^o K^\pm \pi^\mp$ system should come from the K_s^o decay and the other from the primary vertex. The selections used are as follows:

$$p_T(K_s^o K^\pm \pi^\mp) > 2 \text{ GeV/c}, \qquad p_T \text{ (opposite)} > .9 \text{ GeV/c}$$

$$p_T(K_s^o K^\pm \pi^\mp) > p_T(\text{opposite}), \qquad \text{Selection (2)}$$

$$-0.45 \le Y^* \; (K_s^o K^\pm \pi^\mp) \le 0.45.$$

The $K_s^o K^\pm \pi^\mp$ mass spectrum for combinations satisfying these selections is shown in fig. 3, which contains 4157 combinations from 2615 events. It shows no obvious ι signal (the shaded histogram requires $K^\pm$ assignment compatible with Cherenkov information). A 95% confidence level upper limit of 18 events is obtained in the mass interval $1.402 < M(K_s^o K^\pm \pi^\mp) < 1.478$ GeV corresponding to a one Γ interval about the ι mass. This gives an upper limit on the ι cross section of 0.48 μb under selection (2), as given in table 1(b).

In ref. [2], QCD predictions are given for the direct production of high p_T $q\bar{q}$ and gluonium states via higher twist mechanisms. We have presented evidence previously for higher twist ρ^o production in good agreement with these predictions [6]. For the ι prediction the cross section for the helicity 0 (antisymmetric) state is used, while for the Θ we use the sum of the cross sections for the helicity 0 and 2 (symmetric) gluonium states (18% and 82% of the total respectively). Using our result [6] for the higher twist ρ^o cross section and the predicted cross sections for gluonia, we estimate the expected Θ and ι signals in our data. The branching ratios for these two mesons are not well known. We have assumed

$$BR(\Theta(1720) \to K^+K^-) = 0.33 \text{ and } BR(\iota(1440) \to K_s^o K^\pm \pi^\mp) = 0.15, \quad K_s^o \to \pi^+\pi^-$$

and after taking acceptances and efficiencies into account we obtain the expected number of events given in table 1(b). The upper limit for production of the θ is lower than the QCD prediction by a factor of fourteen, while for the ι the predicted signal is compatible with our upper limit.

The cross section predictions require assumptions to be made for the gluonium decay constants and wave functions, that is to say the moments $|f_G\ c_1|$ ($G = \theta, \iota$) in [2] are taken to be 100 MeV. The predicted cross sections are proportional to $|f_G\ c_1|^2$ where all other parameters are calculable.

If the θ and ι are shown to be glueballs then the experimental upper limits given above impose the constraints $|f_\theta\ c_1| < 29$ MeV and $|f_\iota\ c_1| < 300$ MeV.

In conclusion, we observe clear signals for the ρ^o, f^o and ϕ mesons produced at high p_T and obtain the cross sections given in table 1. We do not observe $\theta(1720)$ or $\iota(1440)$ signals and give upper limits for their production.

We have compared our results for the $\theta(1720)$ and $\iota(1440)$ with new detailed predictions for direct production of gg states [2]. Our upper limits impose constraints on their wave functions if these mesons are shown to be glueballs.

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TABLE CAPTIONS

Table 1 (a) Measured cross sections under selection (1) and observed number of events for ρ^o, f^o and ϕ.

(b) Experimental 95% confidence level upper limits on cross sections under selection (2) and number of events for θ and ι compared with the predicted number of events.

TABLE 1(a)

	σ (μb)	No. observed
$\rho^0 \to \pi^+\pi^-$	0.89 ± 0.30	13074 ± 400
$f^0 \to \pi^+\pi^-$	0.36 ± 0.15	5549 ± 450
$\phi \to K^+K^-$	0.038 ± 0.015	1759 ± 83

TABLE 1(b)

	Upper limits		Predictions
	σ (μb)	Events	Events
$\theta \to K^+K^-$	< 0.03	< 265[a]	3720[a]
$\iota \to K^0K^\pm\pi^\mp$	< 0.48	< 18[a]	2[a]

(a) In a one-Γ interval.

FIGURE CAPTIONS

Fig. 1 (a) Example of a higher twist mechanism for the direct production of a ρ^{o} meson.

(b) Example of a higher twist mechanism for the direct production of a glueball.

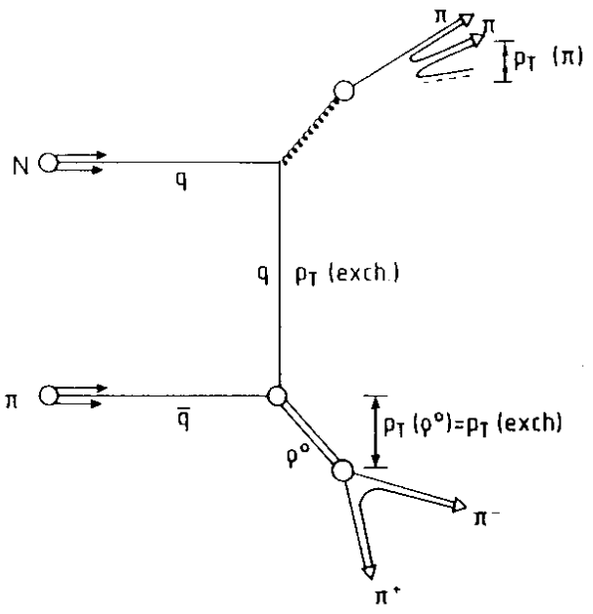
(c) Transverse momentum selection to enhance a signal from the high p_T $\theta(1720)$ decaying to K^+K^-.

(d) As for (c), but for $\iota(1440)$ decaying to $K^{o}_{S}K^{\pm}\pi^{\mp}$.

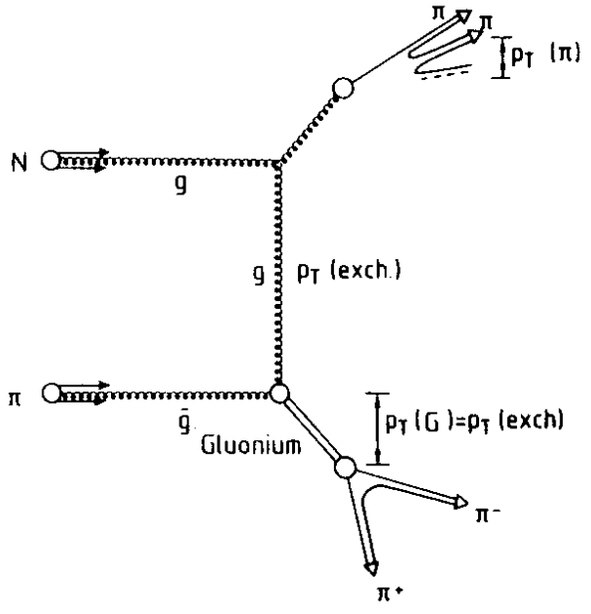
Fig. 2 (a) High p_T pair mass spectrum with mass assignment $\pi^+\pi^-$. The solid line shows the result of a fit [6].

(b) High p_T pair mass spectrum with mass assignment K^+K^-. The shaded histogram is obtained by demanding at least one kaon to be identified in the Cherenkov counters.

Fig. 3 High p_T ($K^{o}_{S}K^{\pm}\pi^{\mp}$) mass spectrum. The shaded histogram is obtained by demanding that the $K^{\pm}$ assignment be compatible with Cherenkov information.

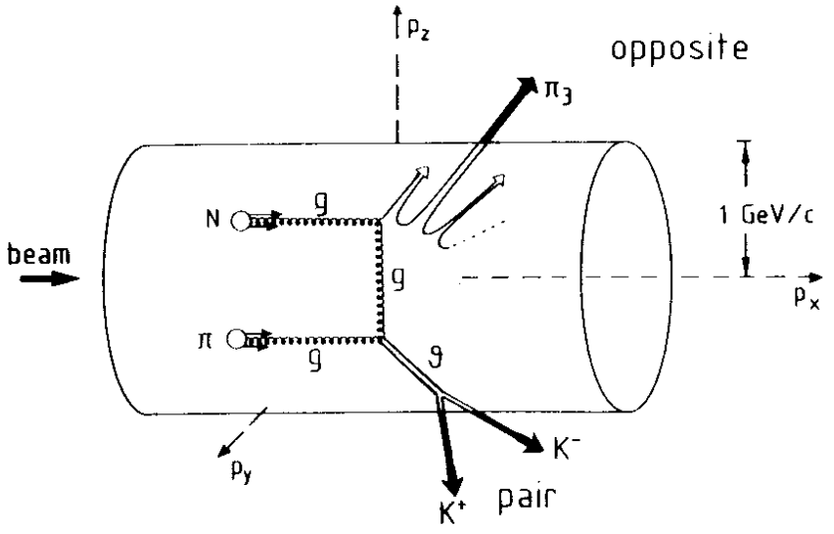

π
π
p_T (π)
N
q
q
p_T (exch.)
π
$\bar{q}$
p_T (ρ°)=p_T (exch)
ρ°
π⁻
π⁺

(a)

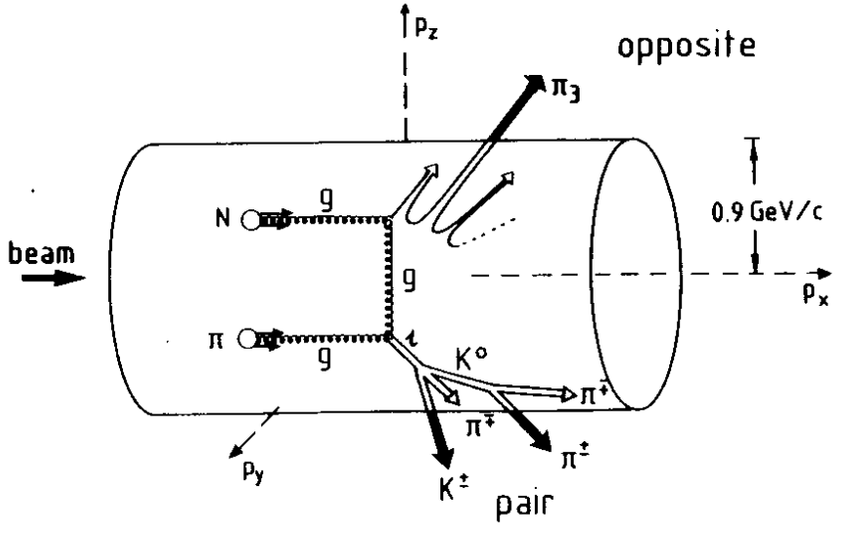

π
π
p_T (π)
N
g
g
p_T (exch.)
π
$\bar{g}$
Gluonium
p_T (G)=p_T (exch)
π⁻
π⁺

(b)

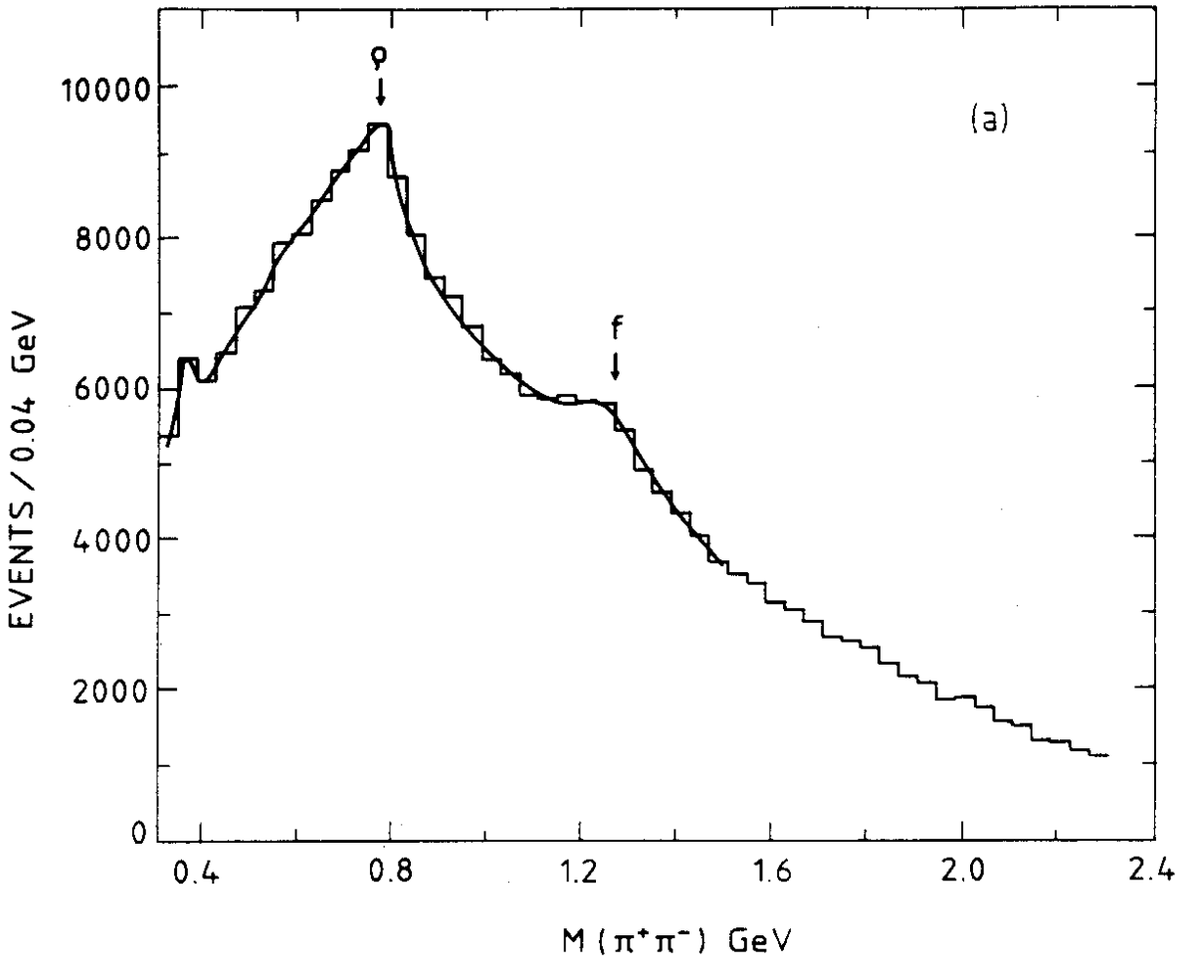
Fig. 1


p_z
opposite
π_3
N
g
beam
g
1 GeV/c
p_x
π
g
g
p_y
K⁻
K⁺
pair

(c)


p_z
opposite
π_3
N
g
beam
g
0.9 GeV/c
p_x
π
g
K°
π⁺
π∓
π∓
p_y
K±
pair

(d)


ρ
f
(a)
10000
8000
6000
4000
2000
0
EVENTS / 0.04 GeV
0.4
0.8
1.2
1.6
2.0
2.4
M (π⁺π⁻) GeV

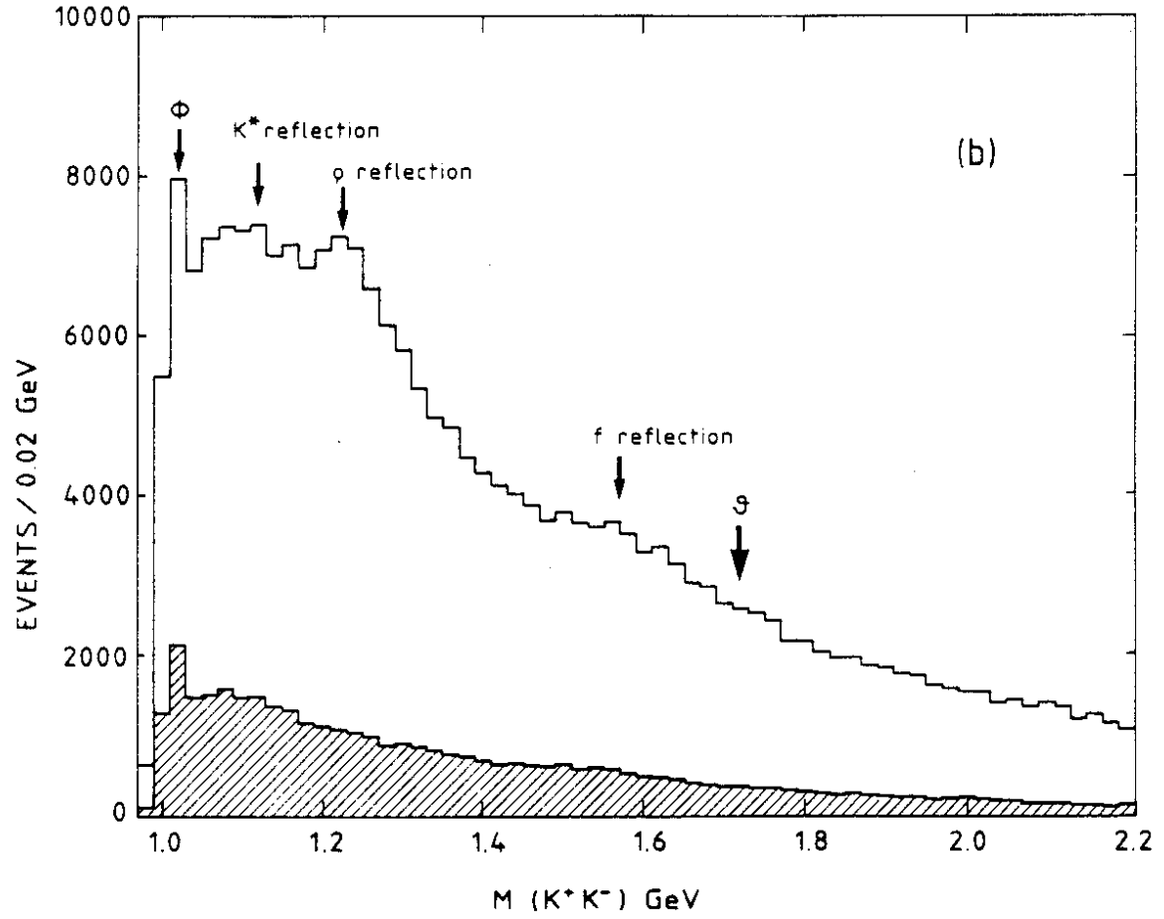

Φ
K* reflection
ρ reflection
f reflection
ϑ
(b)
10000
8000
6000
4000
2000
0
EVENTS / 0.02 GeV
1.0
1.2
1.4
1.6
1.8
2.0
2.2
M (K⁺K⁻) GeV

Fig. 2

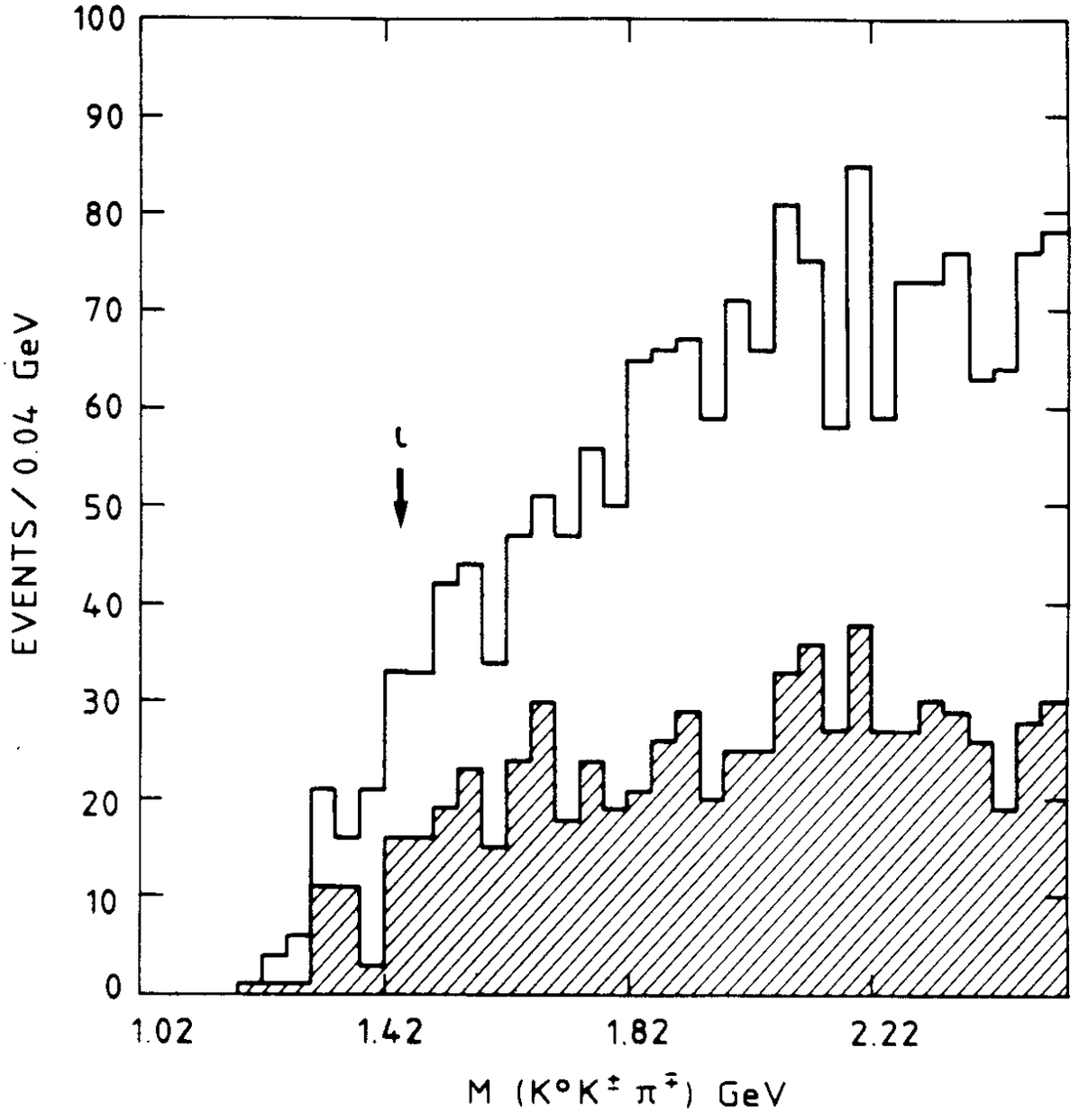

100
90
80
70
60
50
40
30
20
10
0
EVENTS / 0.04 GeV
ι
1.02
1.42
1.82
2.22
M (K°K± π∓) GeV

Fig. 3