EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

A_2 SPLITTING IN THE DECAY CHANNEL $A_2^- \rightarrow K_1^0 K^-$ PRODUCED IN THE REACTION $\pi^- p \rightarrow p A_2^-$ AT 7 GeV/c

The CERN Boson Spectrometer Group

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1. INTRODUCTION

The splitting of the A_2 meson into two separate peaks has been demonstrated with different methods by the CERN Missing-Mass [MMS, 1967][1] and Boson Spectrometer [CBS, 1968][2] experiments. Supporting evidence has also been given by bubble chamber experiments[3-6].

No convincing explanation for this phenomenon has been found. Theoretical discussions are highly speculative so far since the quantum numbers of the two peaks have not been firmly established[7].

Indirect evidence for equal spin-parity of the two peaks, $J^P(A_2^L) = J^P(A_2^H)$, has been deduced from the narrow and deep shape of the dip[2], which could be understood as a result of interference between close-by resonances with equal J^P; however background interference could not be ruled out.

Direct evidence for equal $J^P = 2^+$ was obtained from analyses of the $A_2 \rightarrow 3\pi$ Dalitz plot, both from spark chamber data [MMS, 1967][8] and from bubble chamber data [Böckmann et al., 1968][6]. However, apart from the rather limited statistics published so far, a Dalitz plot analysis of this type is rather complicated and the results depend on certain assumptions about the 3π and the $\rho\pi$ background, which are difficult to assess.

A more direct way of obtaining J^P is to analyse the rare decay channel $A_2^{charged} \rightarrow (K\bar{K})^{charged}$ ($\sim$5% of all decays). The relation $G = (-1)^{I+L}$ holds for the $K\bar{K}$ system. The isospin I is known to be 1, for example from the decay into $K\bar{K}$ and $\eta\pi$. G = -1 from the strong decay into 3π. Hence the orbital angular momentum L of the $K\bar{K}$ system and its parity must be even. A $K_1^0K^\pm$ peak in the A_2 has therefore most probably $J^P = 2^+$ (0^+ is not possible from the $\rho\pi$ mode, 4^+ is unlikely since the A_2 mass is close to the $K\bar{K}$ threshold).

Aguilar-Benitez et al.[5] have studied the reaction $\bar{p}p \rightarrow K_1^0K^\pm\pi^\mp$ at various energies. They observe a dip of 1.5-3 standard deviations in the A_2, which is sitting on a substantial background. They conclude $J^P(A_2^L) = J^P(A_2^H) = 2^+$ as being most probable. However, Crennel et al. reach a different conclusion, $J^P(A_2^L) = 1^-$ and $J^P(A_2^H) = 2^+$, from the observation of a single peak in $K_1^0K_1^0$ [3] compatible in mass with A_2^H, and from the analysis of a narrow peak in $\rho\pi$, produced in K^-n [9] and compatible in mass with A_2^L.

In the present experiment, we have produced a sample of A_2^- in the reaction $\pi^- p \to pA_2^-$ at 7 GeV/c with $A_2^- \to K_1^0 K^-$ using the CERN Boson Spectrometer operating in the Jacobian peak region. A clear double-peaked A_2 is observed in the interesting channel $A_2^- \to K_1^0 K^-$.

2. APPARATUS

A modified version of the CERN Boson Spectrometer used for these A_2 runs is shown in Fig. 1.

The incident beam was momentum analysed to within $\Delta p_1/p_1 = \pm 0.3\%$ by a set of three scintillation counter hodoscopes H_0 H_1 H_2. The absolute incident momentum $\bar{p}_1$ was measured by two independent methods:

i) the deflection of the beam in the spectrometer magnet placed downstream from the target [used for our high mass (0°) runs and not shown in Fig. 1];

ii) the angles of the recoil proton and scattered pion in elastic $\pi^- p$ scattering.

The two independent $\bar{p}_1$ values were found to be in agreement within $p_1 = 0.3\%$.

The recoil proton was identified by range and time-of-flight (TOF) in a "Jacobian peak" telescope.

The proton lab angle θ was measured by two wide-gap wire spark chambers with magnetostrictive read-outs[10] (CH 5 and CH 6) to within $\Delta\theta = \pm 4$ mrad at $\bar{p}_3 = 500$ MeV/c. The full efficiency angular acceptance range was $52.5° < \theta < 64.5°$.

The proton momentum p_3 was measured by two independent TOF circuits between T_2 and R_3 to within $\Delta p_3 = \pm 7.5$ MeV/c at $\bar{p}_3 = 500$ MeV/c. The accepted p_3 interval is $460 < p_3 < 560$ MeV/c.

The missing-mass resolution is $\Delta M_X = \pm 10$ MeV at $M_X = 1.3$ GeV, the full efficiency mass bite $1.05 < M_X < 1.50$ GeV.

The decay products of X^- were detected in the forward spark chambers (CH 1 and CH 2) and their angles measured within an interval of ±22.5° with respect to the beam directions. The target was surrounded by four counters (D_1 to D_4) to count charged particles which miss the chambers 1 and 2. Monte-Carlo studies have shown that the geometrical acceptance of the system for events of the type $A_2^- \to K^- K_1^0 (K_1^0 \to \pi^+\pi^-)$ is 82% under the present conditions.

Data acquisition and monitoring of the spectrometer was done with an on-line computer. The data rate was 200,000 triggers per day.

3. IDENTIFICATION OF $K_1^0K^-$ EVENTS

The identification of events of the type $A_2^- \to K^-K_1^0$ with $K^0 \to \pi^+\pi^-$ was done in several steps (for an example of an event see Fig. 2a):

i) The conservation of energy and momentum was used in a one-constraint fit for the reaction $\pi^-p \to p(K\pi\pi)^-$. This gives the momenta of the decay particles.

ii) The fitted events were required to satisfy the following geometrical criteria (Fig. 2a):

- The K^- track must originate within ±15 mm from the π^-p vertex (V_1), obtained by intersecting the incident π^- and the recoil proton.
- The two decay tracks of the "V" (K_1^0) must intersect in space within ±10 mm. This secondary vertex (V_2) must be downstream from the primary vertex (V_1).
- The direction of the K_1^0, as given by the two vertices V_1 and V_2 must fit the kinematics.

The two-pion effective mass distribution, $M(\pi\pi)$ is shown in Fig. 2b. A rather clean K_1^0 peak appears, at a mass of $M(\pi\pi)$ = 497 MeV with a width of ±9.0 MeV.

iii) K_1^0 events were selected within an interval $485 < M(\pi\pi) < 515$ MeV. As shown in Fig. 2b, the contamination due to background is ∿10% in the final sample.

An additional check of the K_1^0 identification is the lifetime distribution calculated from the distance between the two vertices V_1 and V_2 (Fig. 2c). The fitted lifetime is $\tau = (0.9 \pm 0.1)\ 10^{-10}$ sec.

4. RESULTS

A total of 1.2×10^6 triggers have been taken at p_1 = 7 GeV/c. These consist of three nearly equal runs (each about 2.5 days), taken at different times (June, August, October 1969) and under somewhat different technical conditions, e.g. accelerator performance, beam optimization and intensity, proton range intervals.

251 events of type $A_2^- \to K_1^0 K^-$ have been identified, as described in the preceding paragraph. The distributions of the measured quantities of these events, for example the vertex position, the quark chamber coordinates, the recoil momentum, have been checked in great detail; one third of all events have been plotted and examined visually.

The missing-mass spectrum is presented in Fig. 3, revealing two interesting results:

i) There is a clear dip in the A_2 centre at a mass of 1300 (±5) MeV, which coincides in mass with the splitting observed in the over-all missing-mass spectrum, i.e. for all decay channels (see Table 1).

ii) There is very little (∿10%) background under the A_2, thus ruling out the possibility that the dip is produced by background interference. We have checked that the good single-to-background ratio is not instrumental.

The significance of the dip in Fig. 3 is ∿4 standard deviations. The confidence level for a one-peak (Breit-Wigner) fit gives $P(\chi^2) = 1\%$ over one full width of the A_2 peak, compared to $P(\chi^2) > 60\%$ for a dipole shape[2] (chosen as a convenient parametrization).

In conclusion the present experiment shows that also in the decay channel $A_2^- \to K_1^0 K^-$ the A_2 appears as a double peak. The spin-parities of A_2^{low} and A_2^{high} are therefore equal and most probably 2^+.

This result supports our independent earlier conclusions[1,2], as well as those of Aguilar-Benitez et al.[5]. However, it contradicts the conclusions of Crennel et al.[3,9].

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Table 1

Parameters of the split A_2 (CERN MMS and CBS data)

Experiment	Method	Decay mode	p_1 (GeV/c)	$M(A_2^L)$ (MeV)	$M(A_2^H)$ (MeV)	$\bar{M}$ [dipole] (MeV)	Γ [dipole] (MeV)
MMS[1)] + CBS[2)] (1966-1968)	Jacobian Peak + 0°	all	6; 7; 2.6	1278 ± 5	1318 ± 5	1298 ± 5	28 ± 5
CBS (1969) (this experiment)	Jacobian Peak	$K_1^0K^-$	7	1276 ± 6	1323 ± 6	1300 ± 5	32 ± 5

Figure captions

Fig. 1 : Experimental layout of the CERN Boson Spectrometer, modified to operate in the Jacobian peak region.

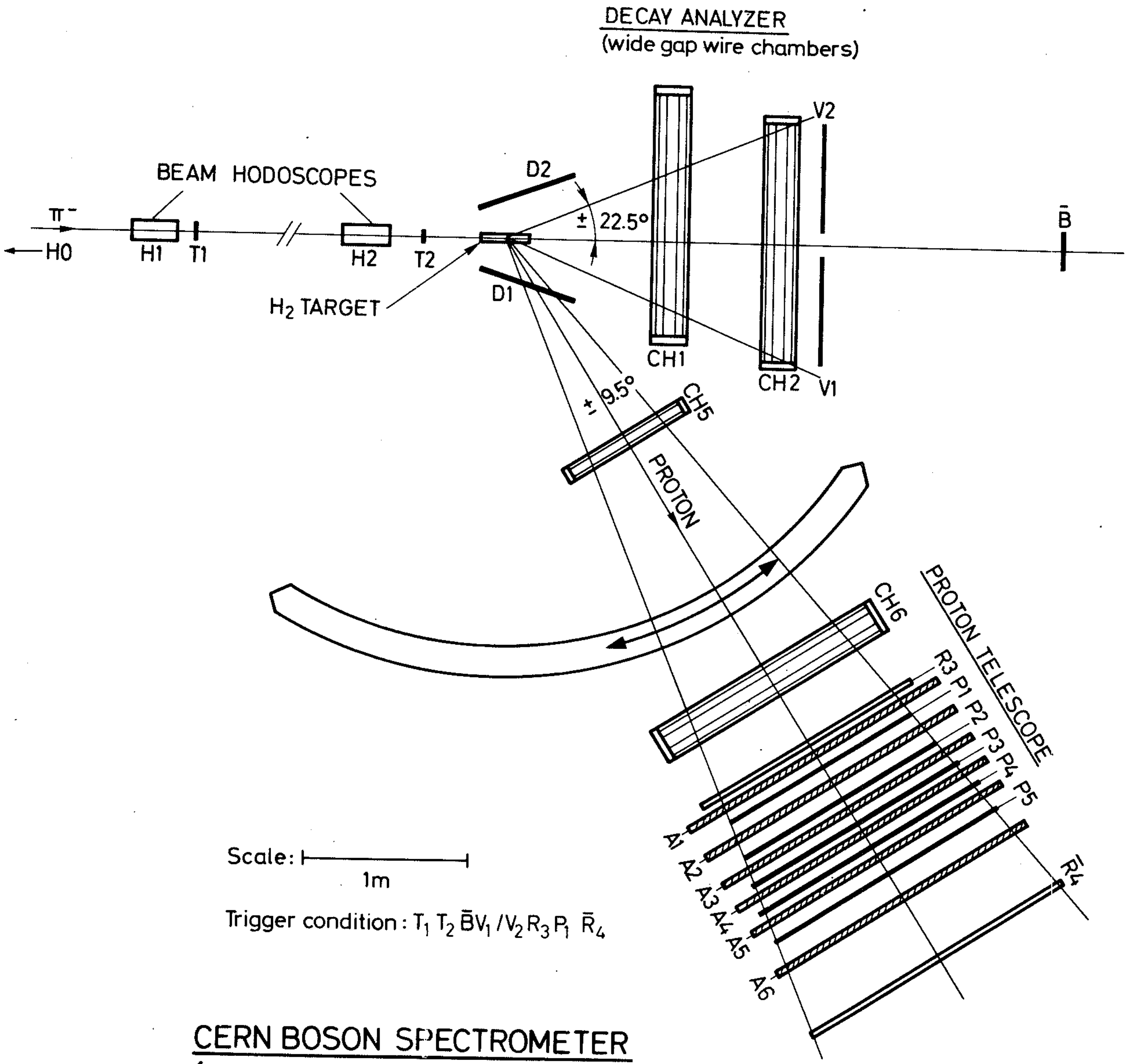
Fig. 2 : Method of identifying the rare events $\pi^- p \to p\ K_1^0 K^-$.

a) Example of a $K_1^0 K^-$ event (to scale).

b) Effective mass distribution $M(\pi\pi)$ of the two charged tracks coming from the second vertex V_2.

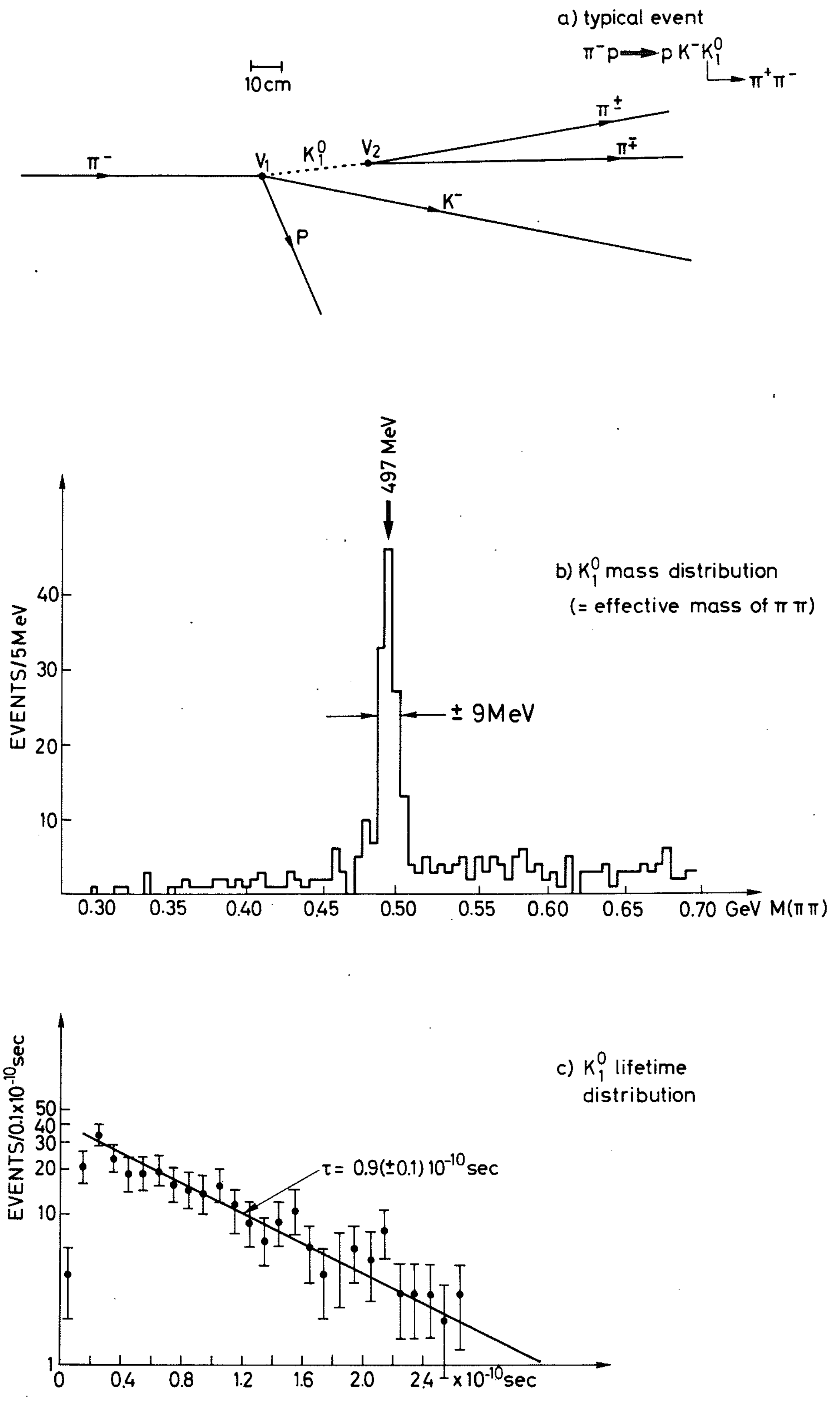
c) Lifetime distribution of the K_1^0, as obtained from the spatial distance between the two vertices V_1 and V_2. The fitted K_1^0 lifetime is $\tau = 0.9\ (\pm 0.1)\ 10^{-10}$ sec.

Fig. 3 : Missing-mass spectrum for $A_2^- \to K_1^0 K^-$ events, produced in $\pi^- p \to pA_2^-$ at $|\bar{t}| = 0.28\ (\text{GeV/c})^2$. The dip is centred at $M = 1300\ (\pm 5)$ MeV. Note the low background level in the A_2 region (no background subtraction).



CERN BOSON SPECTROMETER
(JACOBIAN PEAK VERSION)

Fig. 1



Method of identification of $A_2^- \rightarrow K_1^0 K^-$ events

Fig. 2

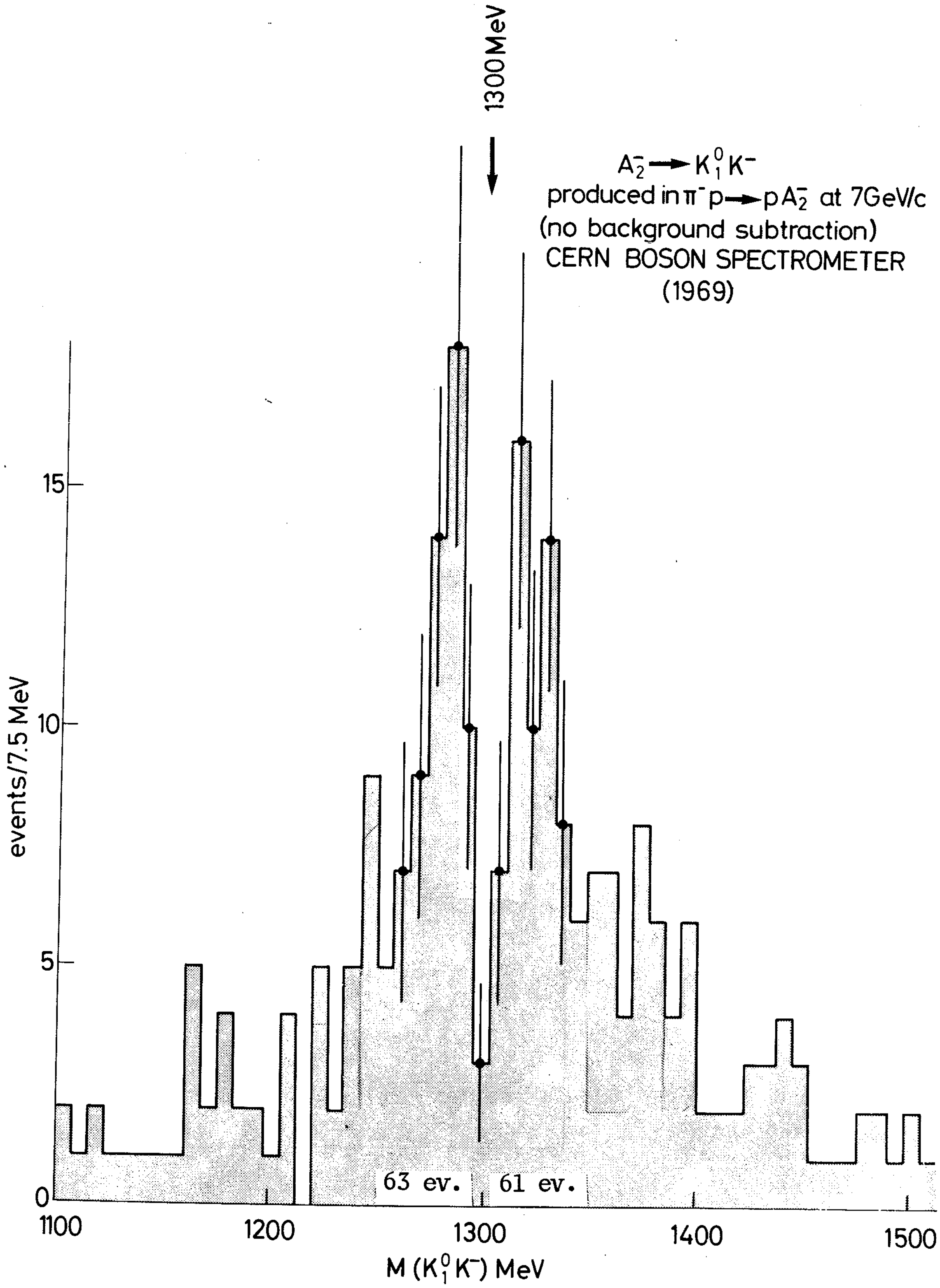

1300 MeV
$A_2^- \rightarrow K_1^0 K^-$
produced in $\pi^- p \rightarrow p A_2^-$ at 7GeV/c
(no background subtraction)
CERN BOSON SPECTROMETER
(1969)
events/7.5 MeV
15
10
5
0
63 ev.
61 ev.
1100
1200
1300
1400
1500
M ($K_1^0 K^-$) MeV

Fig. 3