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Final version
with fits to
the total A_2.

CONFIRMATION OF THE A_2 SPLITTING NEAR THRESHOLD

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ABSTRACT

The shape of the A_2 resonance has been measured in $\pi p \rightarrow pA_2$ at 2.6 GeV/c, i.e. near threshold, with A_2 produced at minimum momentum transfer. The results confirm, with a new method and instrument, the A_2 splitting found previously with the Jacobian-peak method.

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This work is dedicated to G.E. Chikovani (1928 - 1968).

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1. INTRODUCTION

We have explored the shape of the A_2 resonance with a new magnetic mass-spectrometer (CERN Boson Spectrometer, "CBS") which momentum-analyses the forward proton in the reaction $\pi p \rightarrow pA_2$, with A_2 being produced at minimum momentum transfer.

This experiment was done in order to verify whether the two-peak structure of the A_2, first observed in 1965[1] and 1967[2] with the former Missing Mass Spectrometer ("MMS")[3] at 6 and 7 GeV/c, is present also when the A_2 is produced close to threshold.

The new A_2 spectra, obtained at incident momenta near 2.6 GeV/c ($|\bar{t}| = 0.2$ (GeV/c)^2) show again a narrow dip at the A_2 center (1298 ±5 MeV) and thus confirm the A_2 splitting.

2. EXPERIMENTAL METHOD

The kinematical conditions are illustrated in Fig. 1. The missing mass M_X is given by

$$M_X^2 = (E_1 + m - E_3)^2 - p_1^2 - p_3^2 + 2p_1p_3 \cos \theta$$

(p_1 and E_1 refer to the incident pion, θ, p_3, and E_3 to the recoil proton, m is the proton mass, all quantities in the lab. system). At $\theta = 0^\circ$ where $dM_X/d\theta$ vanishes, it is sufficient to measure p_3. Recoil protons near the forward direction are selected in the range $300 < p_3 <$ 900 MeV/c (i.e. $\theta_{c.m.} \cong 180^\circ$) and are momentum-analysed.

The layout and trigger system are shown in Fig. 2. A pion beam, momentum analysed ($\Delta p_1/p_1 = \pm 0.3\%$) by three scintillation counter hodoscopes H_0, H_1, H_2 strikes a hydrogen target 26 cm long.

The recoil proton is detected by the counter R after passing through a spectrometer consisting of a collimator, a large-gap magnet, and four wide-gap wire chambers SC_1 - SC_4[4,5].

The counters V_1 and V_2 require at least one charged decay product of X^-. Four scintillation counters D around the target count additional charged secondaries of X^- which miss SC_1 and SC_2. At low incident momenta, the acceptance of the vertex system is not high enough to allow a decay analysis of $A_2 \to 3\pi^{\pm}$. The full trigger condition is $T_1\ T_2\ \bar{B}$ (V_1 or V_2) R.

The data acquisition and control of the whole spectrometer system is done by an on-line computer.

The proton momentum p_3 and hence M_X is measured in two independent ways: by magnetic deflection, and by time-of-flight (TOF) between the counters T_2 and R. These two measurements allow one to calculate the mass of the recoil particle and to identify it as a proton. The position and width of the proton mass were used to check the stability and resolution of the system.

The total mass resolution at the A_2 center for $p_1 = 2.65$ GeV/c, is composed of contributions from $\Delta p_1/p_1$, $\Delta p_3/p_3$ and from the vertex precision, and amounts to $\Gamma = \pm 5.2$ MeV.

3. RESULTS

A total of 6 runs under different conditions have been taken, as listed in Table 1.

Table 1

A_2 runs with the CBS

Run	p_1 (GeV/c)	Magnetic field B (kG)	Turn-table angle	Fig. Nr.
1	2.60 π^-	3.0	27°	3a
2	2.60 π^-	2.0	18°	
3	2.55 π^-	2.0	18°	
4	2.65 π^-	2.0	18°	
5	2.65 π^+	5.5	30°	3b
6	2.65 π^-	4.15	24°	3c

All data shown in this paper contain the requirement that $X^- \to\ \geqslant 3$ charged decay products in order to improve the signal-to-background ratio. To eliminate the dependence of geometrical efficiency on M_X, events are accepted only if the proton c.m. angle is larger than 176°. The absolute mass scale is known to ±4 MeV, since p_1 was measured with the spectrometer.

Several variations of the experimental conditions were done in order to check against possible instrumental effects:

i) A shift in p_1 from 2.55 to 2.65 GeV/c displaces M_X by 30 MeV for a fixed p_3, and would therefore wash out a false narrow structure.

ii) A change of the beam polarity (positive beam, run 5) in order to operate under different background conditions.

iii) Variations of the magnetic field and the turn-table position as checks against possible biases in the trigger system and spark chambers.

iv) Between runs 4 and 5 the whole system was dismantled and rebuilt with a different geometry.

In spite of these changes, all subsamples show a clear dip at the same mass M_X = 1298 (±5) MeV, as seen in Fig. 3.

The total CBS A_2 data in π^-p are shown in Fig. 4a, as compared to the total MMS A_2 2) in Fig. 4b. The dips in the A_2 center coincide well in mass and in width. The difference of the A_2 signals and the background slopes is due to the different incident momenta.

The sum of CBS + MMS data (Fig. 4c) shows a dip of 7 standard deviations, centred at M_X = 1298 (±5) MeV, the two peaks having the same width and height within statistical errors. The positions and widths of the two A_2 peaks are:

$$\left.\begin{array}{l} A_2^{low} : M_1 = 1278\ (\pm 5)\ \text{MeV} \\ A_2^{high} : M_2 = 1318\ (\pm 5)\ \text{MeV} \end{array}\right\} \Gamma^{low} \cong \Gamma^{high} \cong 22\ (\pm 5)\ \text{MeV.}$$

4. FITS TO THE TOTAL A_2

We have fitted to the total (MMS + CBS) A_2 peak various different resonant shapes as shown in Fig. 5 and listed in Table 2. The data of Fig. 5 are the same as in Fig. 4c, except for the finer bin size. In all fits the experimental gaussian resolution (σ = 5 MeV) has been folded into the fitted curves and the background shape and amplitude left as free parameters.

Hypothesis 1:

Two independent ("incoherent") Breit-Wigner resonances with free positions, widths and heights do not fit the split A_2. The best fit has a confidence level of only P $(\chi^2) \leqslant 0.2\%$, the poorness of the fit coming mainly from the hole region.

(A good fit could be obtained if one assumed that both peaks interfere separately each with as much as 16% of the total background amplitude, and that both background phases were such as to produce maximum destructive interference just at the A_2 center).

Hypothesis 2:

We have therefore allowed for interference between A_2^{high} and A_2^{low}, implying two nearby resonances with equal spin and parity (since we integrate over the A_2 decay angular distribution). Then, good fits are obtained for the following specific solutions:

a) A coherent sum of two Breit-Wigner amplitudes either symmetric in width and height and close in mass or one broad ($\Gamma_1 \approx 90$ MeV) and one narrow ($\Gamma_2 \approx 12$ MeV) and degenerate in mass. The hole is produced by destructive interference.

b) A "Double Pole" (for definition see Ref. 2).

Solutions a) and b) are indistinguishable within our present statistics.

Table 2

Double peak fits to the total (MMS + CBS) split A_2
(Uncertainty in mass $\Delta M = \pm 5$ MeV; in width $\Delta\Gamma = \pm 5$ MeV)

Parameters Hypothesis	M_1 Γ_1	M_2 Γ_2	$P(\chi^2)$
2 incoherent B.W.	1278 22	1318 21	$\leqslant$0.2%
2 coherent B.W. sym. solution	1289 22	1309 22	$\geqslant$ 40%
asym. solution (broad-narrow)	1298 90	1297 12	$\geqslant$ 40%
"Double Pole"	1298 28		$\geqslant$ 40%

In conclusion, the present experiment confirms the splitting of the A_2 meson, which appears, even when produced near threshold, as a roughly symmetric double peak. The total (MMS + CBS) A_2 cannot be fitted by a sum of two independent resonances. A good fit can be obtained assuming that the two peaks interfere or form a double pole; this would imply that A_2^{high} and A_2^{low} have the same spin-parity[6].

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4) G. Chikovani, G. Laverrière and P. Schübelin, Nucl. Instrum. Methods 47, 273 (1967).

6) This would agree with the results of Aguilar-Benitez et al. (Vienna Conference, 1968) who observe a double peaked A_2 in the $K_1^oK^\pm$ system; our conclusion disagrees however with D.J. Crennell et al, Phys. Rev. Letters 20, 1318 (1968), who observe in the $K_1^oK_1^o$ system only A_2^{high}.

Figure captions

Fig. 1 : Kinematics of the reaction $\pi p \rightarrow pX$ at 2.6 GeV/c. The shaded area near $\Theta = 0^{\circ}$ lab.angle indicates the region of full efficiency of the Boson Spectrometer during the A_2 runs ($0.3 \leq p_3 \leq 0.9$ GeV/c and $0^{\circ} \leq \theta_{lab} \leq 10^{\circ}$.)

Fig. 2 : Boson Spectrometer layout (schematic). H_1 and H_2: beam hodoscopes. SC_1 - SC_4 are wide-gap wire spark chambers operating in the track following mode (gap size 5 cm, sensitive area 1.5×1.5 m^2). The system operates on-line with the IBM 1800 computer.

Fig. 3 : Mass spectra of the A_2 region obtained in $\pi^{\pm}p \rightarrow pX^{\pm}$ near A_2 threshold with the CBS at different experimental conditions.

Fig. 4 : Compilation of the total available mass spectrometer data relevant to an A_2 splitting in $\pi^{-}p \rightarrow pX^{-}$:

a) Total CERN Boson Spectrometer ("0° method") data, A_2 produced close to threshold (p_1 near 2.6 GeV/c).

b) Total CERN Missing-mass Spectrometer ("Jacobian-peak method") data, A_2 produced far above threshold (p_1 = 6 and 7 GeV/c).

c) TOTAL SUM = sample (a) + sample (b).

Fig. 5 : Two-peak fits to the total (MMS + CBS) A_2 data.

FIG.1 KINEMATICS OF THE REACTION $\pi p \rightarrow pX$ AT INCIDENT MOMENTUM $P_1 = 2.6$ GEV/C

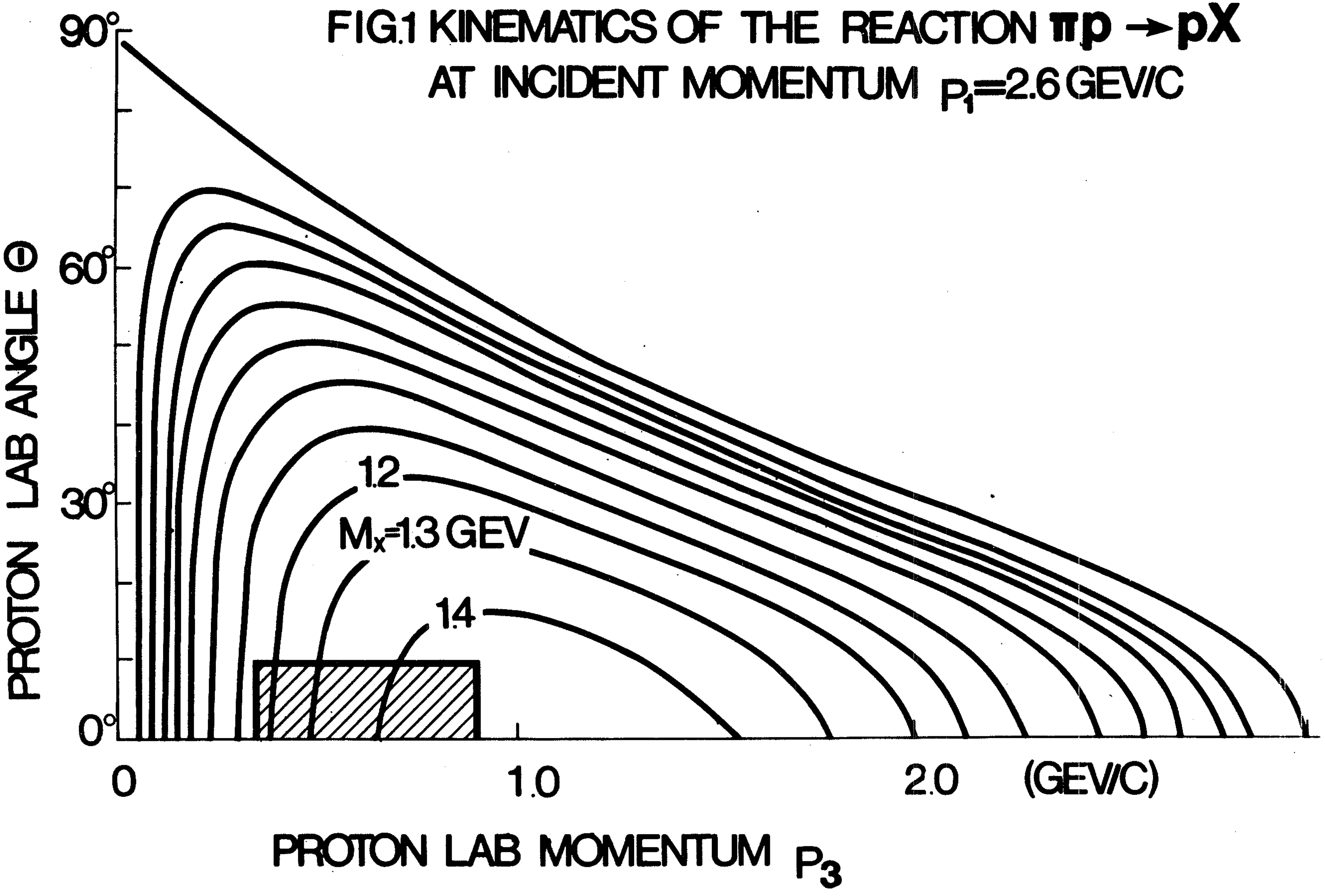
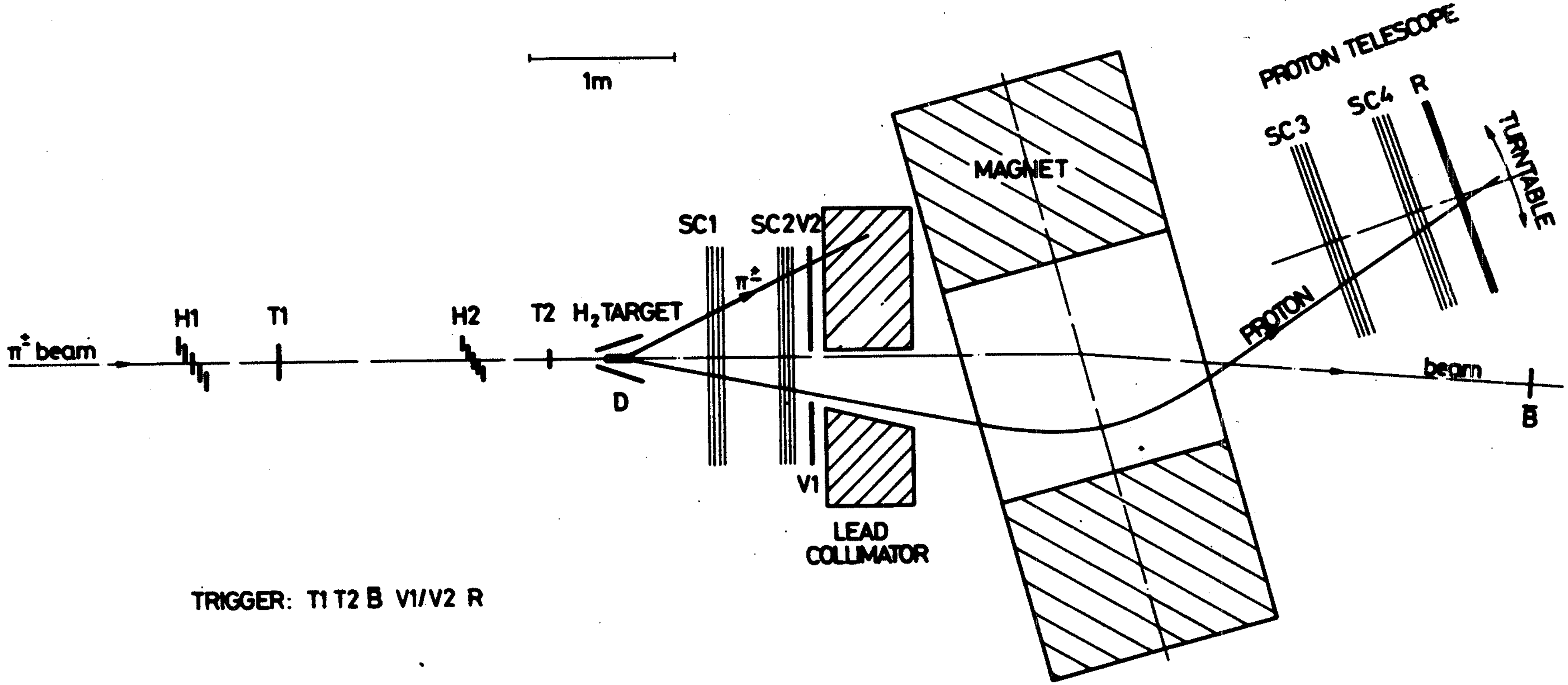


FIG. 2 BOSONSPECTROMETER LAYOUT 1968 (SCHEMATIC)



TRIGGER: T1 T2 $\bar{B}$ V1/V2 R

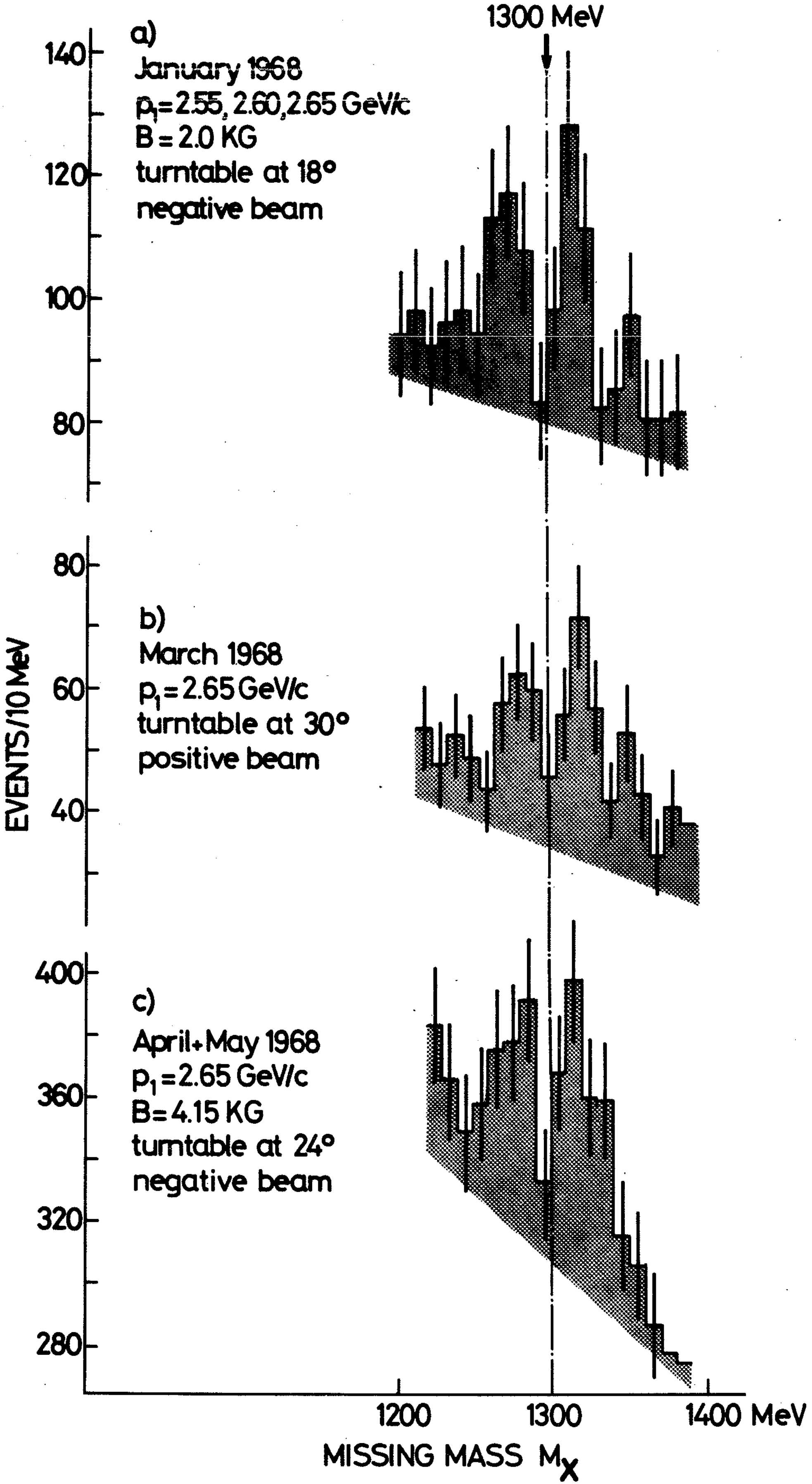


FIG.3 Mass spectra of the A2 region obtained in $\pi p \rightarrow pX$ with the CERN Boson Spectrometer (1968) under different experimental conditions.

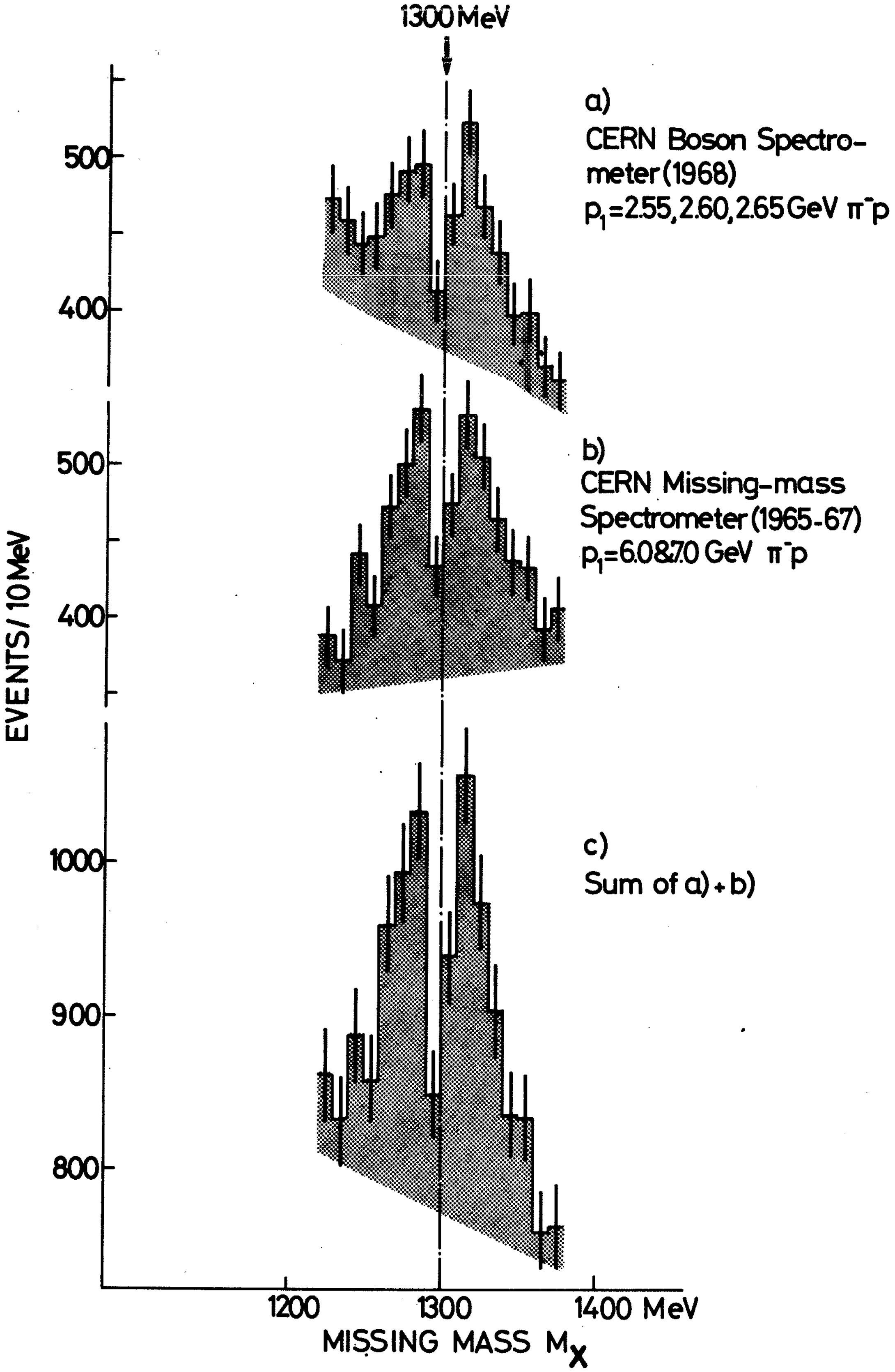


FIG. 4 Compilation of the total A2 data from CERN Boson Spectrometer (0° method) 1968, and CERN Missing-mass Spectrometer (Jacobian peak method) 1965-67.

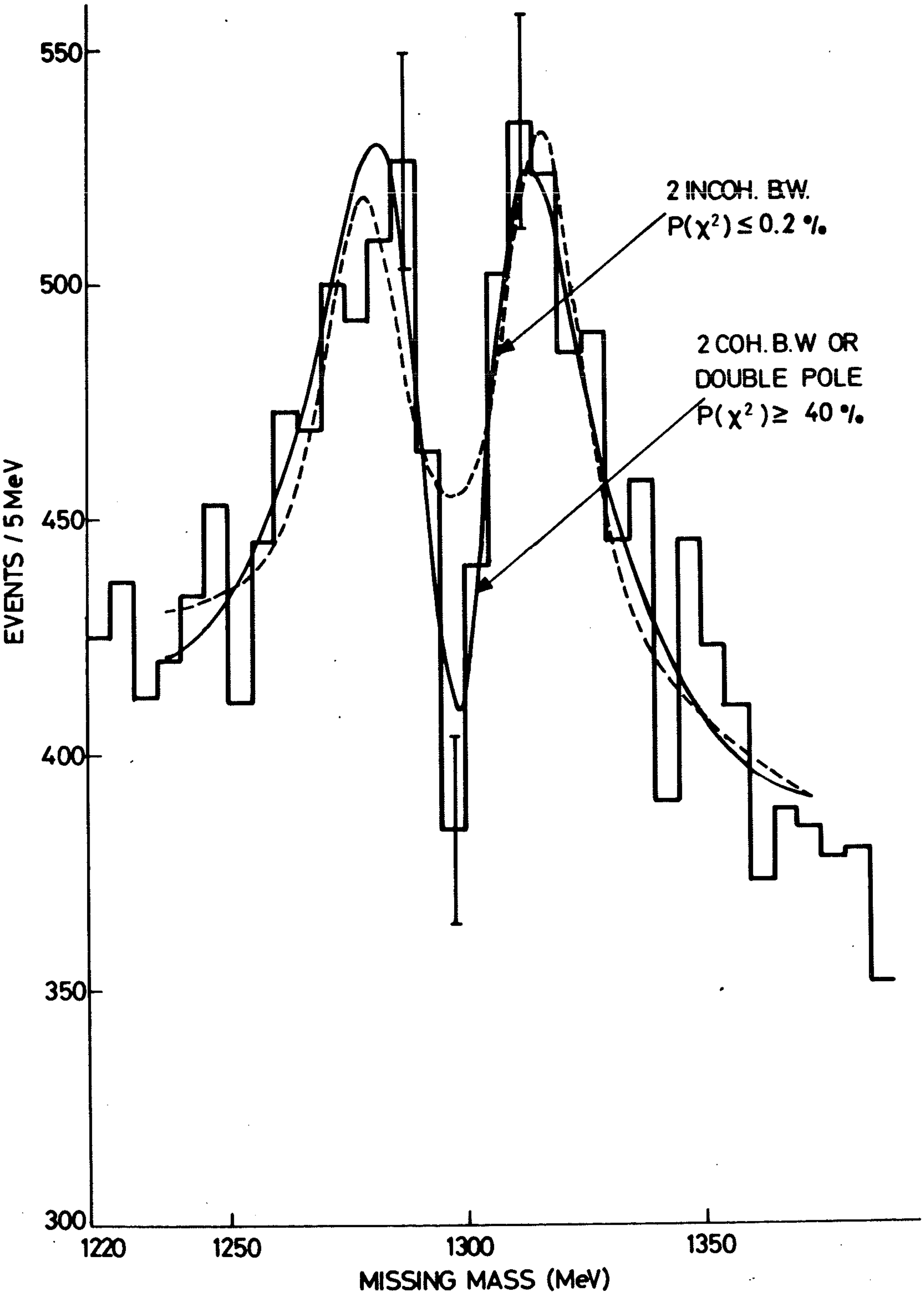


FIG. 5 FITS TO THE TOTAL (MMS + CBS) A2 DATA