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CHARACTERISTICS OF THE A_1 AND A_2 MESONS

Aachen - Berlin - CERN Collaboration

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An enhancement in $\pi^+\pi^-\pi^-$ effective mass distribution was observed by Bellini et al. [1] and Huson and Fretter [2]. This was shown to be a π-ρ enhancement by Goldhaber et al. [3] and then it was proved that there were two resonances A_1 and A_2 by the British-German collaboration [4] and by Chung et al. [5] Here we report results on the production of A_1 and A_2 mesons by 8 GeV/c positive pions in hydrogen.

On 50.000 photographs taken in the 81cm Saclay hydrogen bubble chamber with a beam of 8.04 $\pm$ 0.06 GeV/c positive pions from the CERN Proton Synchrotron, some 3.000 two prong and some 3.000 four prong events were measured and analysed using the THRESH-GRIND-BAKE-SLICE-SUMX or similar systems. Separation of protons from pions were made by Mean Gap Length measurements on tracks of up to 2 GeV/c.

607 events of the reaction

$$\pi^+ p \longrightarrow p\pi^+\pi^+\pi^- \qquad (1)$$

were identified. As reported by the Aachen-Berlin-CERN collaboration [6], about half the events proceed through the two-body reaction

$$\pi^+ + p \longrightarrow N^{*++} + \rho^0 \qquad (2)$$

In the remaining events N^{*++}, ρ-meson and f^0-meson production occurs frequently. If we reject all events in which N^{*++} production takes place (defined as having a $(p\pi^+)$ effective mass between 1.12 and 1.34 GeV), then there remains a sample of 304 events. In Fig. 1 is plotted the effective mass of the $(\pi^+\pi^+\pi^-)$ combinations (205 events) in which at least one $(\pi^+\pi^-)$ combination is consistent with the mass of a ρ-meson. It can be seen that there are two distinct peaks with relatively little background. The reduction of background compared with that obtained with 3 to 4 GeV/c incident pions is probably due to the peripheral nature of the interactions [6] at 8 GeV/c which facilitates the assignment of pions to the baryonic or mesonic vertex (assuming that one can represent the reaction by Feynmann-type graphs).

To these two peaks in the $(\rho^0\pi^+)$ effective mass, we assign to the A_1 and A_2 mesons. The arrows on Fig. 1 are at 1080 MeV and at 1320 MeV, the value at the peaks reported by the British-German collaboration. For the A_1 we find a value of 1.03 $\pm$ 0.2 which may be different from those previously reported due to the lower background; for the A_2 peak, the value found of 1.28 $\pm$ 0.02 is consistent with the earlier values.

The Dalitz plot of the decay of the A_2 meson is shown in Fig. 2. The two boundaries correspond to the upper and lower mass limits taken. For convenience, each event is plotted twice. Two bands at the ρ-meson mass are seen with what appears to be a constructive interference in the overlap region. This effect is shown more clearly at the bottom of Fig. 2 by the projection of the points in the ρ-band on an axis. The data are consistent with the A_2 having a spin and parity of 1^+, 2^+ or 2^-. From the observation by Chung et al.[5] of the decay of A_2 into $K_1^o K_1^o$ and into $K_1^o K^-$ combinations, the 2^+ assignment is favoured.

In the two-prong interactions, 547 events were found with an identified proton and which gave no kinematical fit to the elastic reaction $\pi^+ p \longrightarrow \pi^+ p$ or to the single pion production reaction $\pi^+ p \longrightarrow \pi^+ p\pi^o$. These events were considered to be of the reaction

$$\pi^+ + p \longrightarrow \pi^+ + p + X \qquad (3)$$

where X is the effective total of the missing neutral particle(s). In Fig. 3 is shown a plot of the $(\pi^+ X)$ effective mass for the 271 events found with Δ^2, the square of the four-momentum transfer, of less than $0.6(\mathrm{GeV/c})^2$ and after removal of all events with the $(p\pi^+)$ effective mass in the N^{*++} region. It can be seen that there is a pronounced peak near 1250 MeV. This peak might be from B-mesons which decayed into $\pi^+\omega$ and then the ω decayed by its neutral mode. However since the decay into $(\pi^+\pi^-\pi^o)$ of the ω-meson is 8.5 times more probable than the neutral[7], the number of events to be expected in the reaction $\pi^+ p \longrightarrow p\pi^+\pi^+\pi^-\pi^o$ in which the B-meson decays into $\pi^+\omega$ and the ω then into $\pi^+\pi^-\pi^o$, would be an order of magnitude greater than is observed. It is possible that the peak is the A_2 meson decaying into $(\pi^+\pi^o\pi^o)$ with one of the $(\pi^+\pi^o)$ combinations being a ρ-meson. From kinematic considerations, one would expect the distribution of the $(\pi^o\pi^o)$ effective mass, in our case the mass of X, to give a broad enhancement near 750 MeV, as is in fact found.

If the isotopic spin of A_2 is one or two, then it can decay with equal probability into $(\rho^o\pi^+)$ and $(\rho^+\pi^o)$. Comparing the number of events in Fig. 1 and Fig. 3 it can be seen that the numbers are consistent with equal decay probabilities, so that the isospin of A_2 is one or two.

Nauenberg and Pais [8] and Peierls [9] have predicted the existence of a $(\rho\pi)$ resonance with a mass of about 1090 MeV. Such a resonance has the property that the $(\rho^{+}\pi^{o})$ decay mode is forbidden. As we observe for A_2 this decay mode, it may be concluded that A_2 is not the Nauenberg - Pais - Peierls enhancement.

In Fig. 3, there is no evidence for a peak at 1030 or 1090 MeV for the A_1 resonance. If the isotopic spin of A_1 were one or two, then the same number of events at the A_1 peak should be seen in Fig. 3 as are observed in Fig. 1 for the $(\rho^{o}\pi^{+})$ decay mode. It may then be concluded that the isotopic spin of A_1 is not one or two. There is no evidence against the A_1 being the Nauenberg - Pais - Peierls enhancement.

FIG. 1

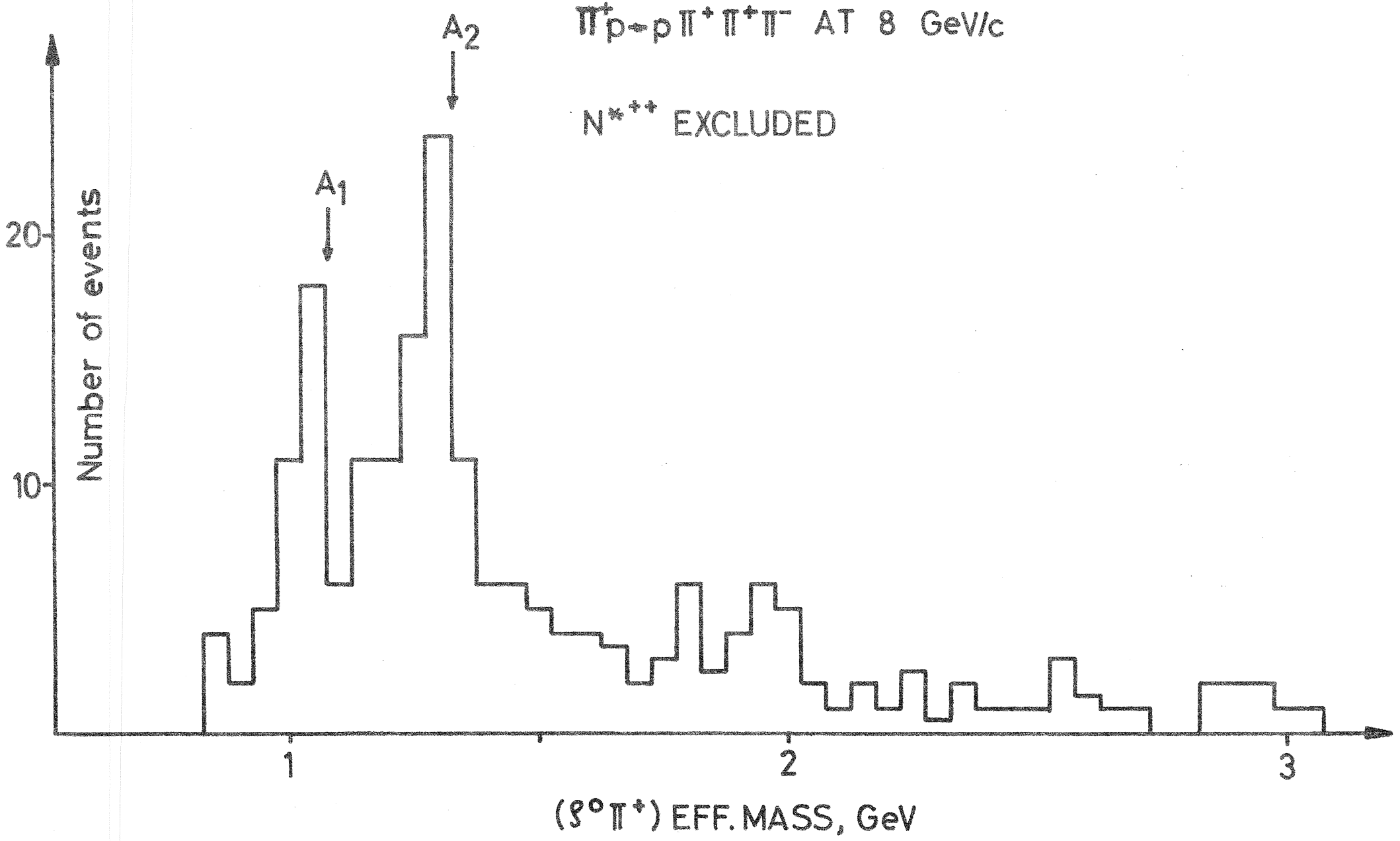
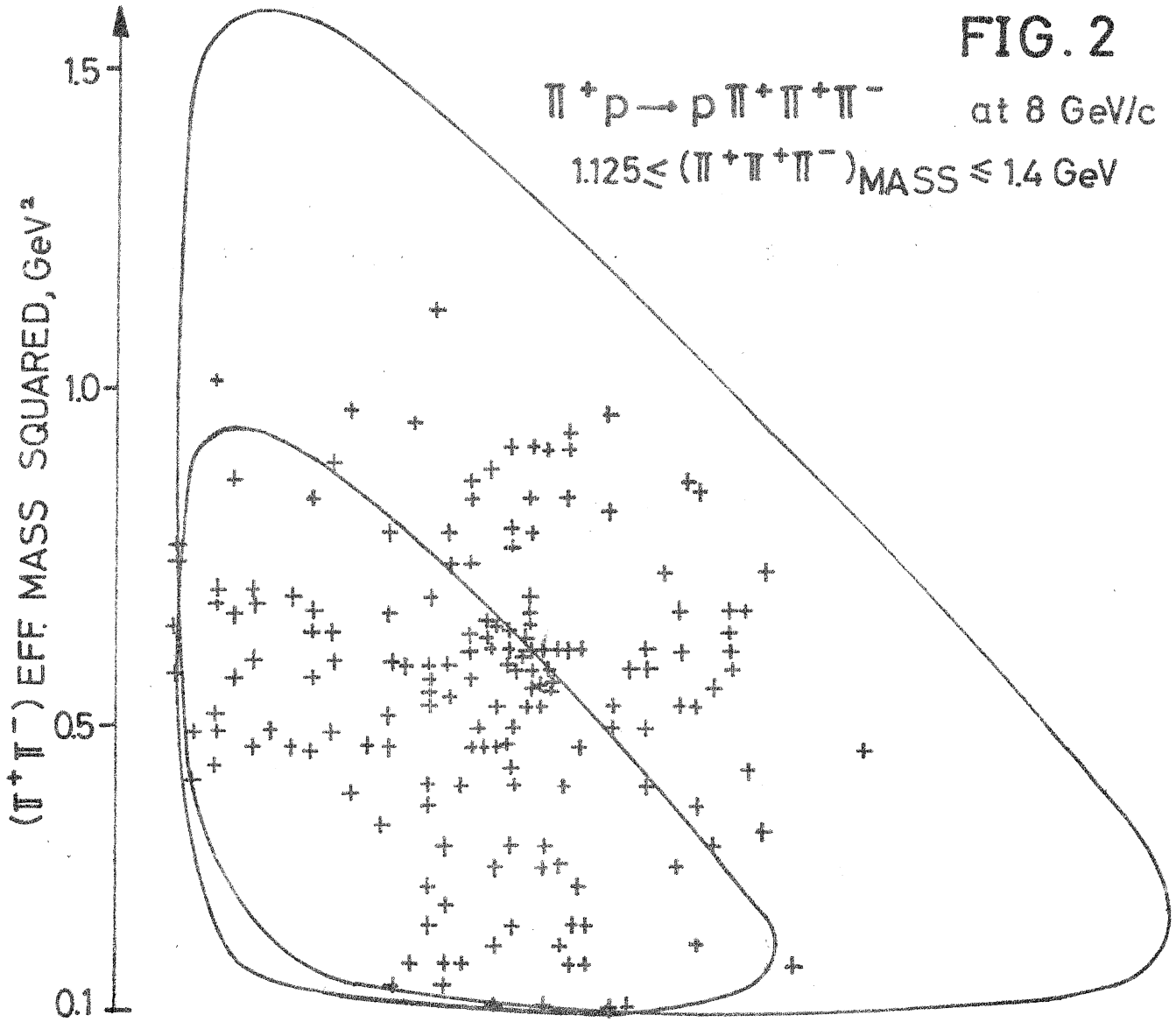
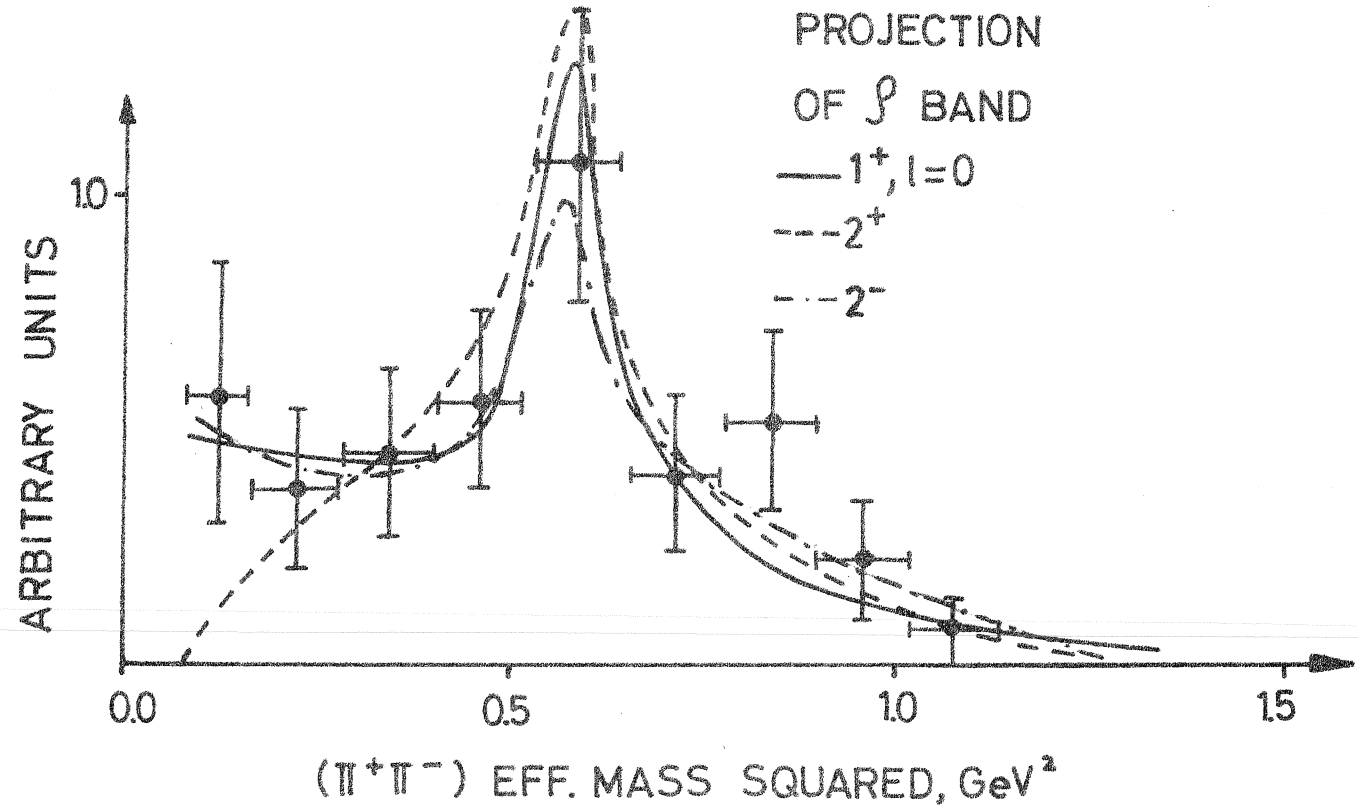

$\pi^+ p \to p\pi^+\pi^+\pi^-$ AT 8 GeV/c
N^{*++} EXCLUDED
A_1
A_2
Number of events
20
10
1
2
3
$(\beta^0\pi^+)$ EFF. MASS, GeV

FIG. 2


$\pi^+ p \rightarrow p\pi^+\pi^+\pi^-$ at 8 GeV/c
$1.125 \leq (\pi^+\pi^+\pi^-)_{MASS} \leq 1.4$ GeV
$(\pi^+\pi^-)$ EFF. MASS SQUARED, GeV²
1.5
1.0
0.5
0.1


PROJECTION
OF ρ BAND
—— 1⁺, I=0
– – – 2⁺
– · – 2⁻
ARBITRARY UNITS
1.0
0.0
0.5
1.0
1.5
$(\pi^+\pi^-)$ EFF. MASS SQUARED, GeV²

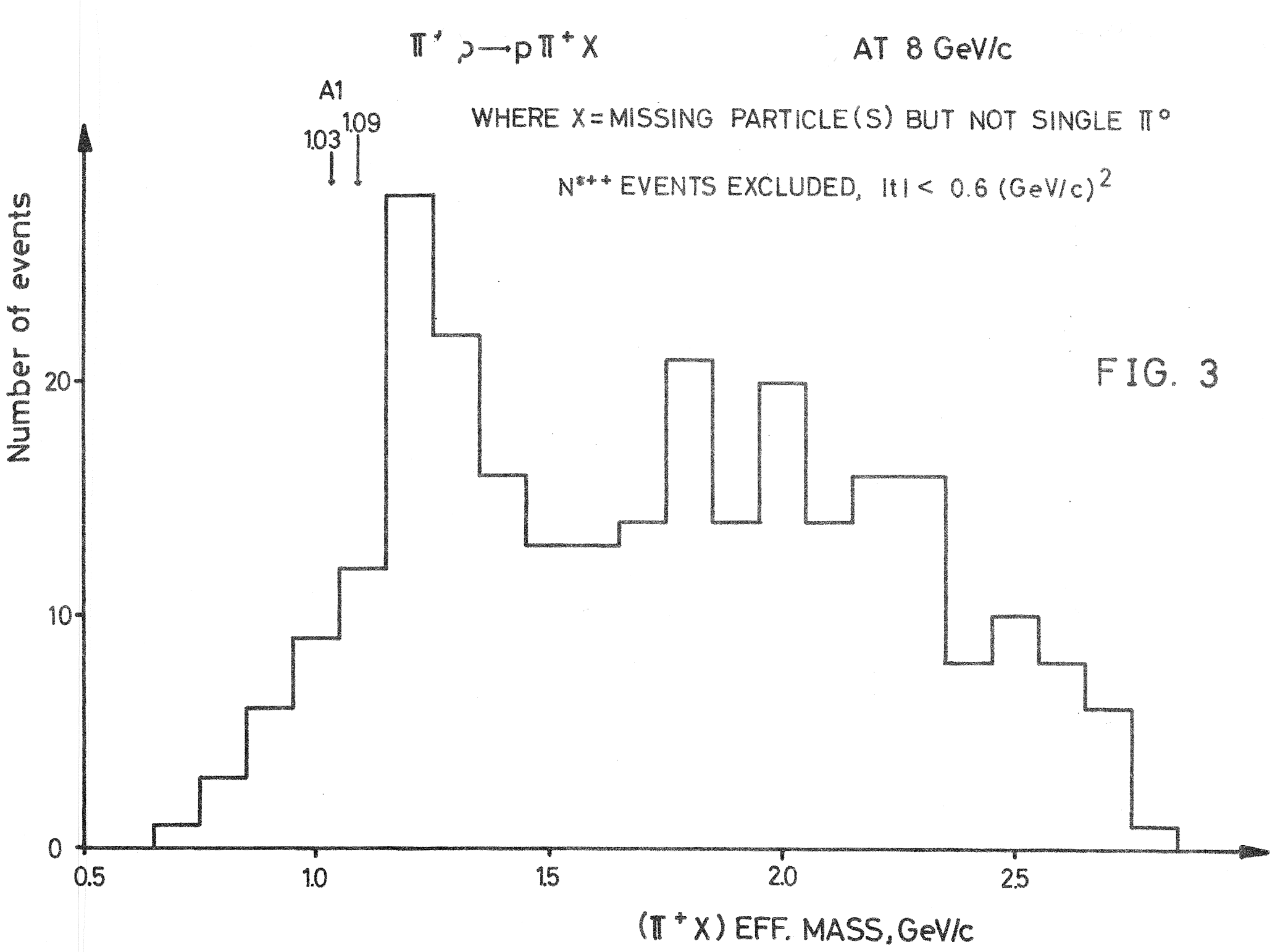

π⁻ p → p π⁺ X
AT 8 GeV/c
A1
1.03
1.09
WHERE X = MISSING PARTICLE(S) BUT NOT SINGLE π°
N*⁺⁺ EVENTS EXCLUDED, |t| < 0.6 (GeV/c)²
Number of events
0
10
20
0.5
1.0
1.5
2.0
2.5
(π⁺ X) EFF. MASS, GeV/c

FIG. 3