Title

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THE φ/ω AND η/η' PRODUCTION RATIOS IN THE REACTION $\pi^+p \rightarrow \Delta^{++}$ + BOSON AT 3.7 GeV/c*

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I. THE φ/ω RATIO

It is well known that the reaction $\pi p \rightarrow \Delta\varphi$ is suppressed.[1] In a new high-statistics experiment with π^+p at 3.7 GeV/c we are getting data which indicates just how enormously the reaction

$$\pi^+p \rightarrow \Delta^{++}\varphi \qquad (2^{+3}_{-2} \text{ events}) \tag{1}$$

is suppressed relative to the reaction

$$\pi^+p \rightarrow \Delta^{++}\omega \qquad (1324\pm 100 \text{ events}) \quad . \tag{2}$$

Here the center-of-mass momenta are $p_\varphi = 0.83$ GeV/c and $p_\omega = 0.96$ GeV/c so that phase space corrections are small. We thus obtain a cross section ratio of:

$$\rho = \frac{\sigma(\pi^+p \rightarrow \Delta^{++}\varphi)}{\sigma(\pi^+p \rightarrow \Delta^{++}\omega)} = \frac{1}{662} = 0.0015^{+0.0023}_{-0.0015} \quad .$$

It is interesting to note that this ratio is in good agreement with the squared coupling constant ratio $g^2{\varphi\rho\pi}/g^2{\omega\rho\pi} \approx 1/600$ determined collectively from the experimental ω and φ widths, the $\varphi \rightarrow \rho\pi$ branching fraction, and the ratio between the phase spaces available for $\varphi \rightarrow \rho\pi$ and $\omega \rightarrow \rho\pi$.[2]

In our experiment we have analyzed about 60,000 four-prong events from an exposure of 180,000 pictures taken in the LRL 72-inch hydrogen bubble chamber in a 3.7-GeV/c π^+p beam at the Bevatron. These yielded 15,066 events fitted and identified as

$$\pi^+p \rightarrow \pi^+\pi^-\pi^0\pi^+p \qquad (3)$$

and 353 events fitted and identified unambiguously as

$$\pi^+p \rightarrow K^+K^-\pi^+p \quad . \qquad (4)$$

In Fig. 1 we show a triangle plot of $M(K^+K^-)$ vs $M(p\pi^+)$. In Fig. 2 we show the projection on the $M(p\pi^+)$ axis. The K^+K^- spectrum, shown in Fig. 3, indicates clearly that we observe φ production (~ 18 events). However, there is no indication (see Fig. 4) that φ production occurs in association with Δ^{++}. Furthermore we note that φ production occurs at comparatively large t values (see Fig. 5), a result similar to that observed for π^-p interactions.[3] We have examined the $\pi^+\varphi$ and $p\varphi$ mass distributions to find out whether the φ production here observed is associated with any higher mass meson or baryon system. No hint of any such effect is observed within our very limited φ data, which is consistent with uniform mass distributions. Thus the reaction $\pi^+p \rightarrow \pi^+\varphi p$ appears to a nonperipheral process leading to three "particles" in the final state.

A. Mixing Angle Determination on a Quark Model

In the framework of the quark model the smallness of ρ can be interpreted in terms of the quark content of the φ and ω mesons; namely, they are almost entirely $\lambda\bar{\lambda}$ and $n\bar{n} + p\bar{p}$ respectively. Alexander et al.[4] have related R to the $\omega\varphi$ mixing angle θ_1 by:

$$\pm\,|R| = \frac{\langle\pi^+p/\varphi\Delta^{++}\rangle}{\langle\pi^+p/\omega\Delta^{++}\rangle} = \frac{\cos\theta_1 - \sqrt{2}\sin\theta_1}{\sin\theta_1 + \sqrt{2}\cos\theta_1} = \tan(\theta_0 - \theta_1)$$

where θ_0 = arctan $(1/\sqrt{2}) = 35.26^\circ$ and $|R| = \sqrt{\rho}$. This relation gives a model-dependent determination of the mixing angle, but is independent of meson masses in the nonet. We find $|\theta_0 - \theta_1| = 2.2^\circ {}^{+1.3^\circ}_{-2.2^\circ}$. In principle this method could yield information on whether the quadratic or linear form of the Gell-Mann/Okubo mass formula is appropriate for the bosons.[5,6] In practice however the values are sufficiently close; namely, $|\theta_1(\text{quadratic})| = 39.9^\circ \pm 1.1^\circ$ and $|\theta_1(\text{linear})| = 37.1^\circ \pm 1.1^\circ$, that our data cannot distinguish between them. Our results are: $\theta_1(R = +\sqrt{\rho}) = 33.1^\circ {}^{+2.2^\circ}_{-1.3^\circ}$ or $\theta_1(R = -\sqrt{\rho}) = 37.5^\circ {}^{+1.3^\circ}_{-2.2^\circ}$. This result is displayed graphically in Fig. 6.

II. THE η/η' RATIO

In this same experiment we have observed 139±12 events ascribed to[7]

$$\pi^+ p \rightarrow \Delta^{++}\eta$$
$$\quad\quad\quad \hookrightarrow \pi^+\pi^-\pi^0$$

and 39±10 events for

$$\pi^+ p \rightarrow \Delta^{++}\eta'$$
$$\quad\quad\quad \hookrightarrow \pi^+\pi^-\eta_n$$

where we used a "narrow" Δ^{++} definition $M(p\pi^+)$ = 1160-1280 MeV.

Using the Particle Data Tables,[8] we find the 139 observed η events correspond to 594±58 η events where all decay modes are taken into account. Using the data of Rittenberg,[9] we find our observed η' events correspond to 127 ± 33 η' events where again all decay modes are taken into account. These two numbers give $\rho = 4.7 \pm 1.3$, where ρ is the ratio of $\Delta^{++}\eta$ events to $\Delta^{++}\eta'$ events.

Again, we have used the formula of Alexander et al.[4] to evaluate the η/η' mixing angle. To make this comparison we multiply the above number of $\Delta^{++}\eta$

events by a factor such that the result corresponds to the same outgoing center-of-mass momentum in both cases, namely $p_{cm} = 0.853$ GeV/c. The magnitude of this factor is obtained from the shape of the $\Delta^{++}\eta$ cross section as determined by Brown et al.[10] Inclusion of the appropriate phase space and flux factors with this factor gives an overall correction factor of 0.93 to be applied to ρ. Thus we find from $R = \pm\sqrt{0.93\ \rho} = \tan(\theta_o - \theta)$ that $\theta(R = +\sqrt{\rho}) = -29.0^o \pm 3.3^o$ and $\theta(R = -\sqrt{\rho}) = -80.4^o \pm 3.3^o$. In this case the linear Gell-Mann/Okubo formula gives $|\theta| = 23.7^o \pm 0.3^o$ and the quadratic formula gives $|\theta| = 10.4^o \pm 0.2^o$. Thus our result is in agreement with the linear GMO formula, which is the conclusion obtained by Benson et al.[6]

Of course, this conclusion depends on the validity of the quark model[4] and on the identification of the $\eta'(958)$ as the ninth member of the pseudoscalar nonet rather than some other candidate such as the E(1420).

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*Work supported by the U. S. Atomic Energy Commission.

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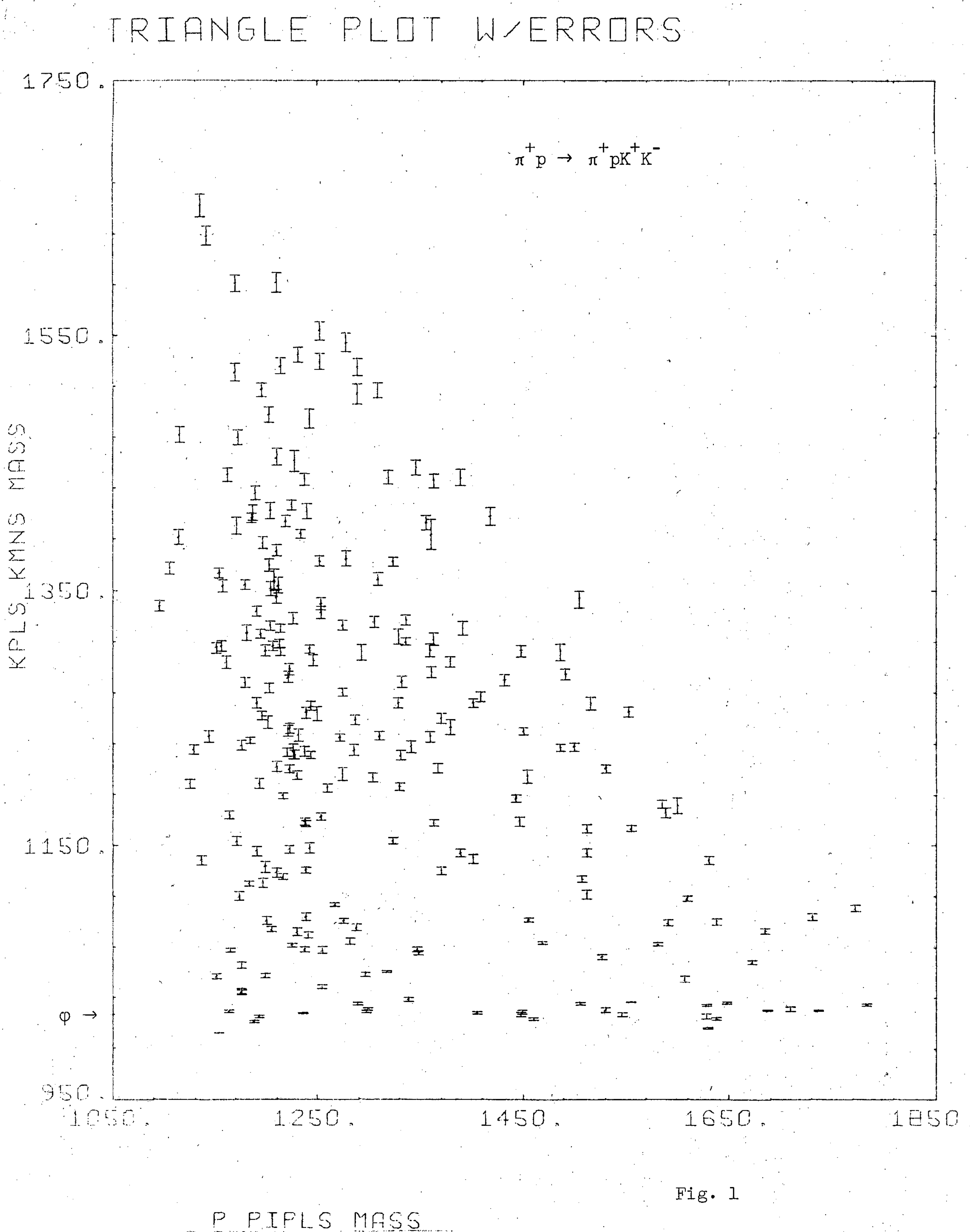

TRIANGLE PLOT W/ERRORS
$\pi^+ p \rightarrow \pi^+ p K^+ K^-$
1750.
1550.
1350.
1150.
950.
$\varphi \rightarrow$
KPLS KMNS MASS
1050.
1250.
1450.
1650.
1850.
P PIPLS MASS

Fig. 1

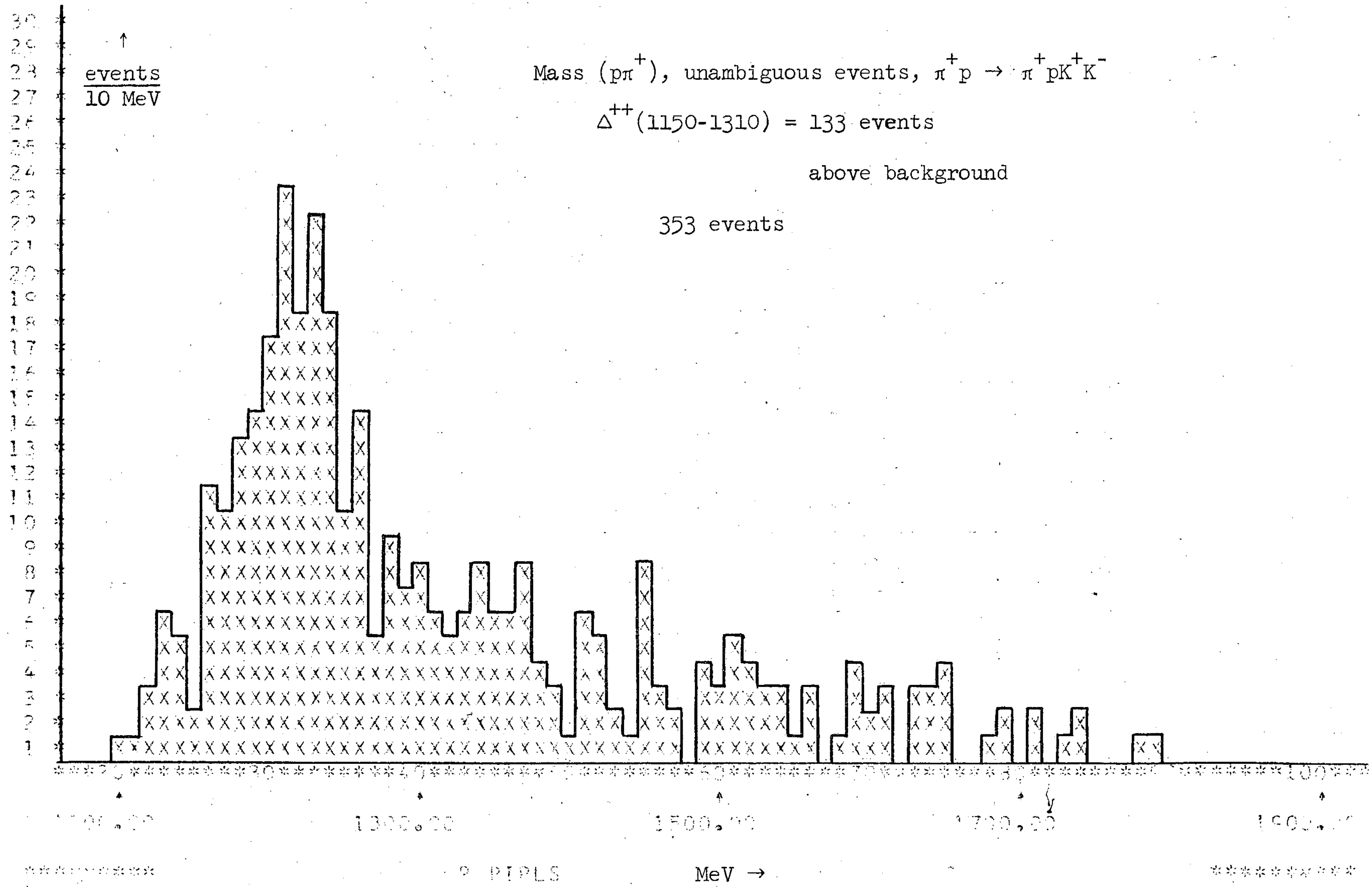

events / 10 MeV
Mass (pπ+), unambiguous events, π+p → π+pK+K-
Δ++(1150-1310) = 133 events
above background
353 events
1300.00
1500.00
MeV →

Fig. 2

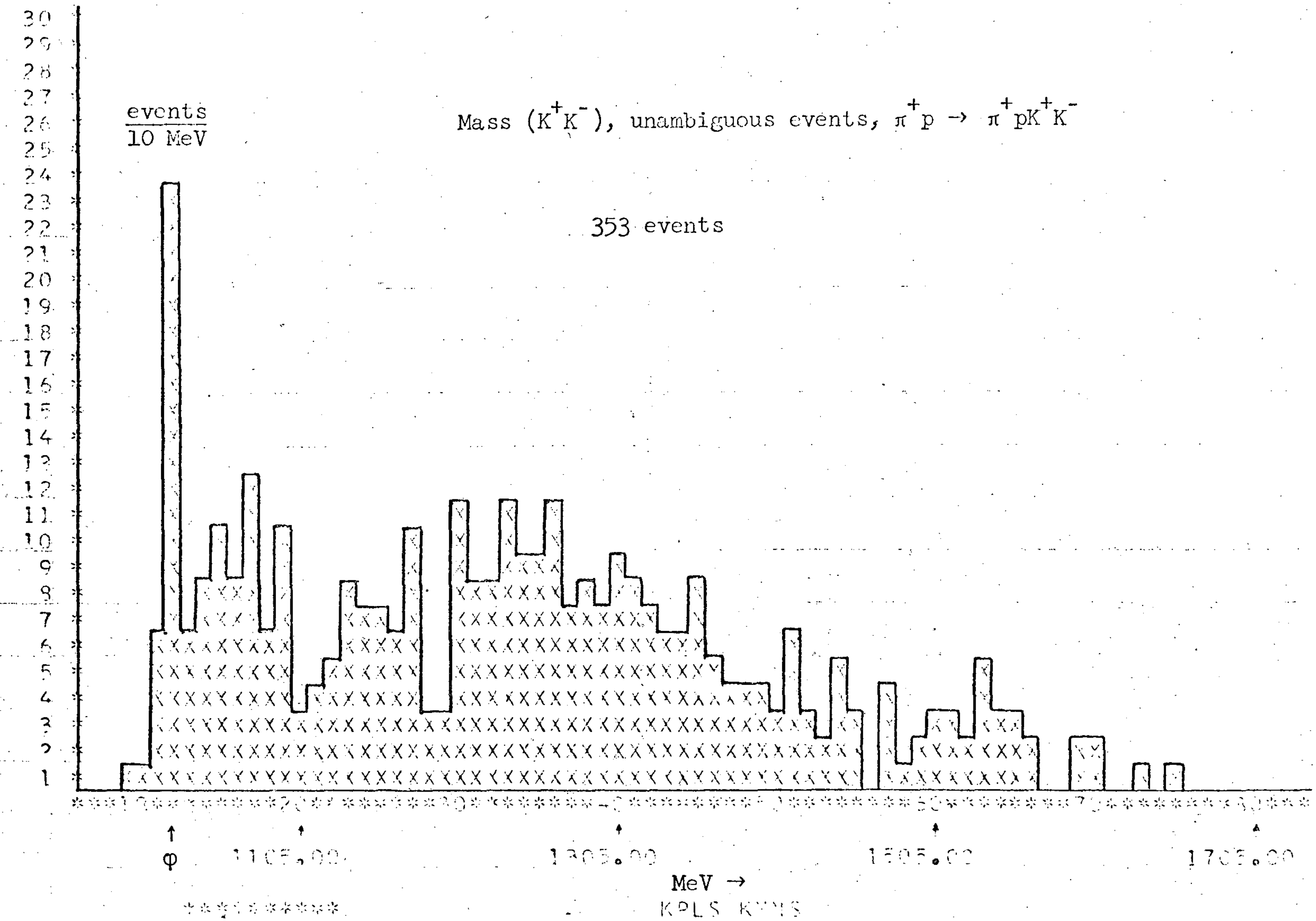
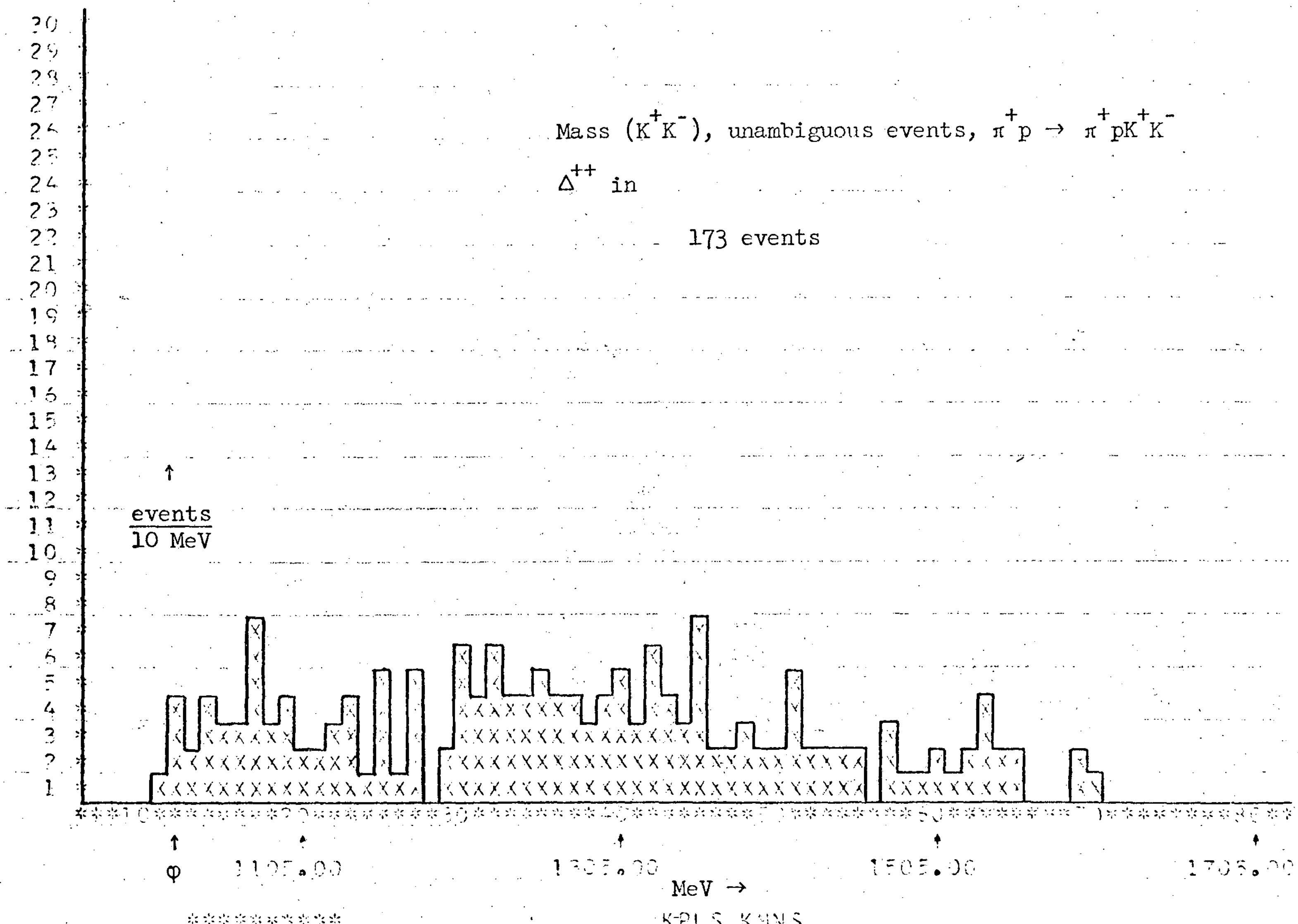

events / 10 MeV
Mass (K+K-), unambiguous events, π+p → π+pK+K-
353 events
φ
MeV →

Fig. 3



Mass (K^+K^-), unambiguous events, $\pi^+p \to \pi^+pK^+K^-$
Δ^{++} in
173 events
events / 10 MeV
φ
1105.00
1305.00
1505.00
1705.00
MeV →

Fig. 4

CHEW-LOW PLOT

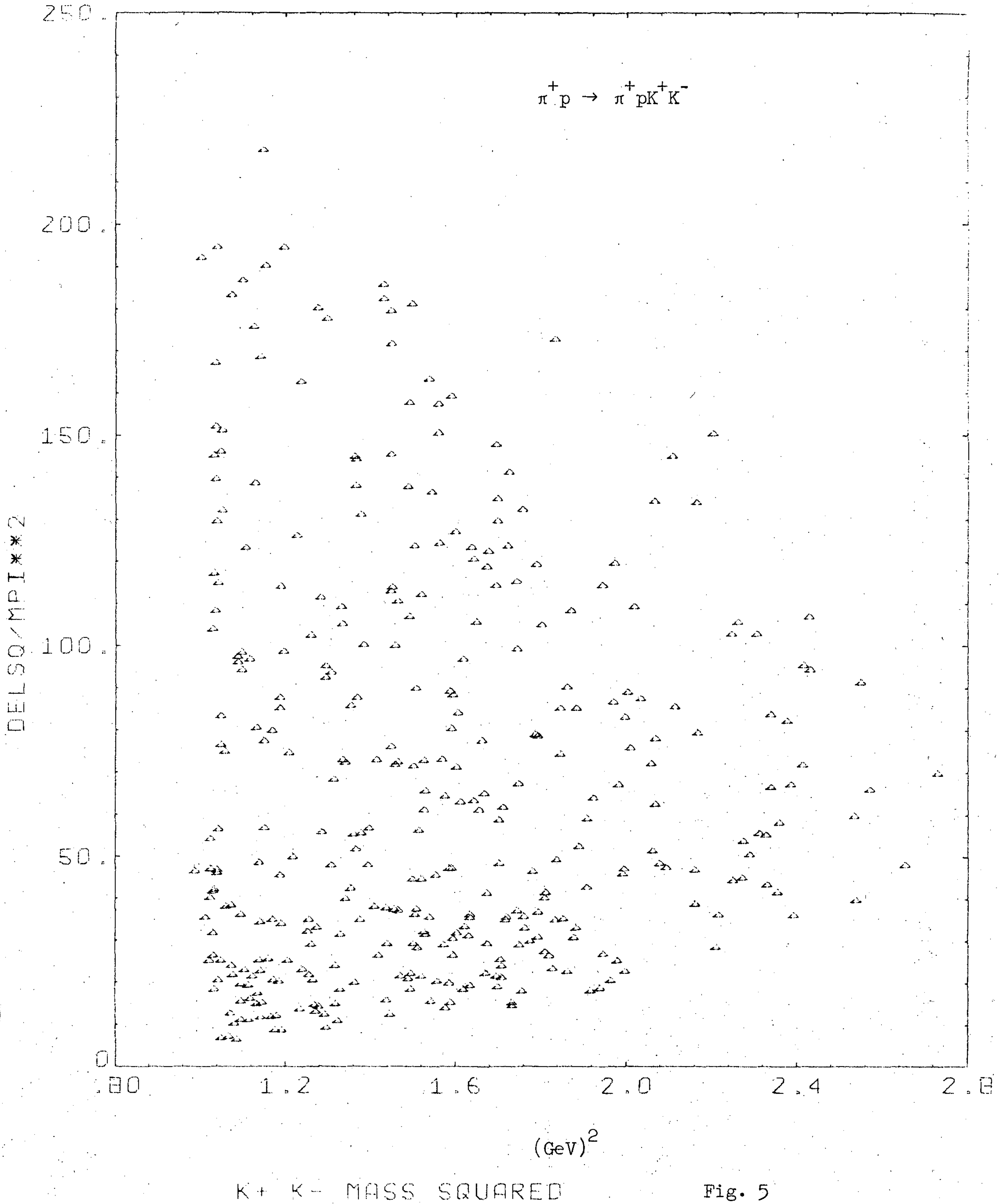


Fig. 5

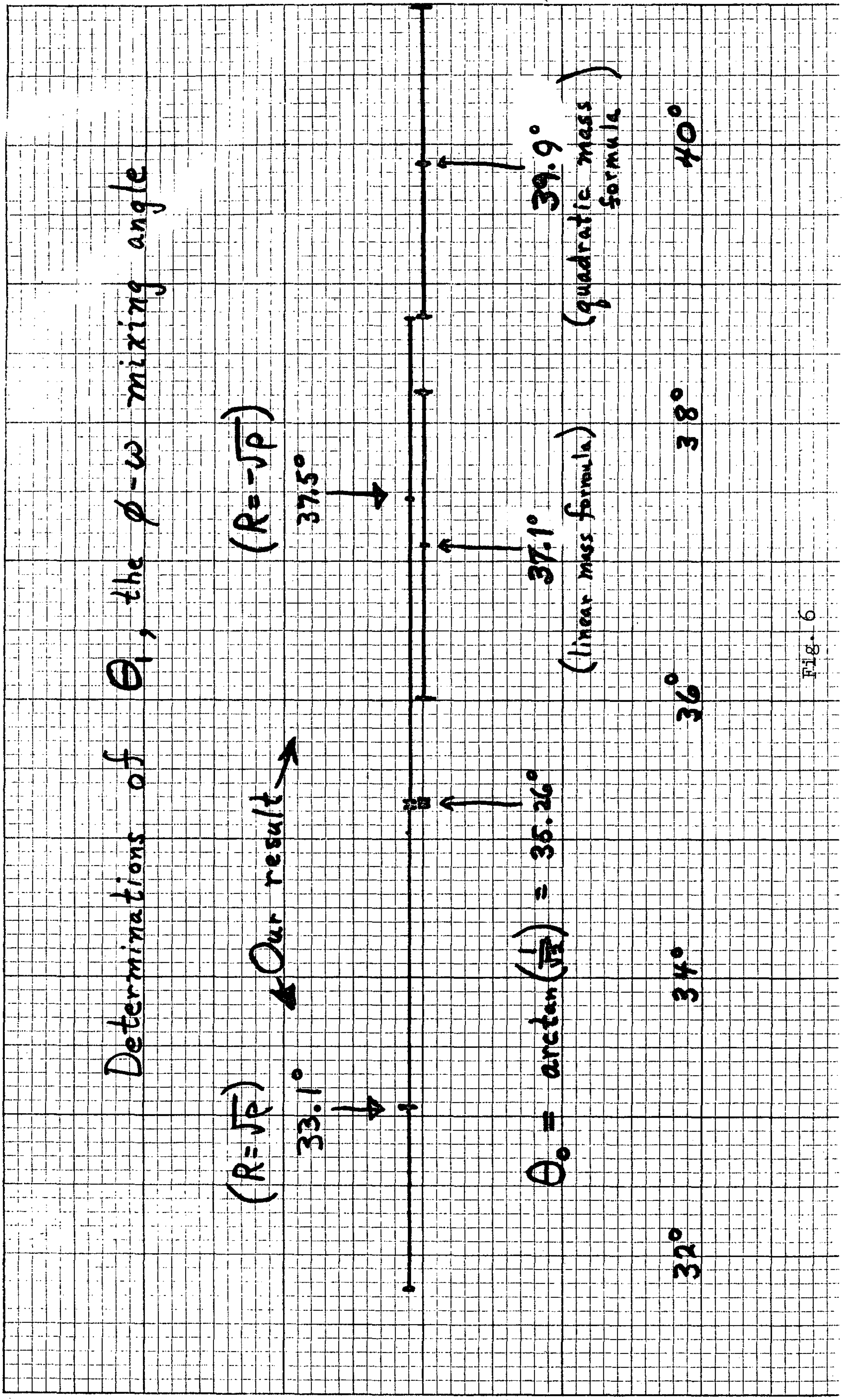

Determinations of Θ₁, the φ-ω mixing angle
(R=√p) 33.1°
Our result
(R=-√p) 37.5°
Θ₀ = arctan(1/√2) = 35.26°
37.1° (linear mass formula)
39.9° (quadratic mass formula)
32°
34°
36°
38°
40°

Fig. 6

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