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Conference on Elementary Particles,
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THE φ/ω AND η/η' PRODUCTION RATIOS IN THE REACTION $\pi^+p \to \Delta^{++}$ + BOSON AT 3.7 GeV/c*

W. R. Butler, D. G. Coyne, G. Goldhaber, B. H. Hall, J. N. MacNaughton, and G. H. Trilling

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I. THE φ/ω RATIO

It is well known that the reaction $\pi p \to \Delta\varphi$ 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

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

is suppressed relative to the reaction

$$\pi^+p \to \Delta^{++}\omega \qquad (1324\pm100 \text{ events}) \quad . \tag{2}$$

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:

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

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 $\varphi \to \rho\pi$ branching fraction, and the ratio between the phase spaces available for $\varphi \to \rho\pi$ and $\omega \to \rho\pi$.[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

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

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 $\theta_0 = \arctan(1/\sqrt{2}) = 35.26^\circ$ 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]

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

and 39±10 events for

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

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

REFERENCES

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

1. G. H. Trilling, J. L. Brown, G. Goldhaber, S. Goldhaber, J. A. Kadyk, and J. Scanio, Physics Letters 19, 427 (1965).
2. Joel Yellin, Phys. Rev. 147, 1080 (1966).
3. O. I. Dahl, L. M. Hardy, R. I. Hess, J. Kirz, and D. H. Miller, Phys. Rev. 163, 1377 (1967).
4. G. Alexander, H. Lipkin, and F. Scheck, Phys. Rev. Letters 17, 412 (1966).
5. K. W. Lai and T. G. Schumann, A New Experimental Determination of the Mixing Angles of Meson Nonets Using Recent Quark Model Prediction, BNL-B-48, June 1966, Contribution to the XIIIth International Conference on High-Energy Physics, Berkeley 1966.
6. G. Benson, L. Lovell, C. T. Murphy, B. Roe, D. Sinclair, and J. Vander Velde, Production Cross Sections for η, ω, η', φ, and f^0 Mesons in π^+d Interactions at 3.65 BeV/c, Contribution to the XIIIth International Conference on High-Energy Physics, Berkeley 1966.
7. G. Goldhaber, W. R. Butler, D. G. Coyne, B. H. Hall, J. N. MacNaughton, and G. H. Trilling, Further Study of the H(990) Effect, UCRL-19229, Contribution to the Lund International Conference on Elementary Particles, June 25-July 1, 1969.
8. Alan Rittenberg (Lawrence Radiation Laboratory, Berkeley) quoted by A. Barbaro-Galtieri and P. Söding, Is There Evidence for an H Meson? (Is It Just the η'?), Proceedings of the University of Pennsylvania Conference on Meson Spectroscopy, Philadelphia, April 26-27, 1968, C. Baltay and A. H. Rosenfeld, editors.
9. N. Barash-Schmidt, A. Barbaro-Galtieri, L. R. Price, A. H. Rosenfeld, P. Soding, C. G. Wohl, M. Roos, and G. Conforto, Rev. Mod. Phys. 41, 109 (1969).

10. David G. Brown, π^+p 4-Prong Interactions Between 3 and 4 GeV/c (Ph. D. thesis), Lawrence Radiation Laboratory Report UCRL-18254, May 1968 (unpublished).

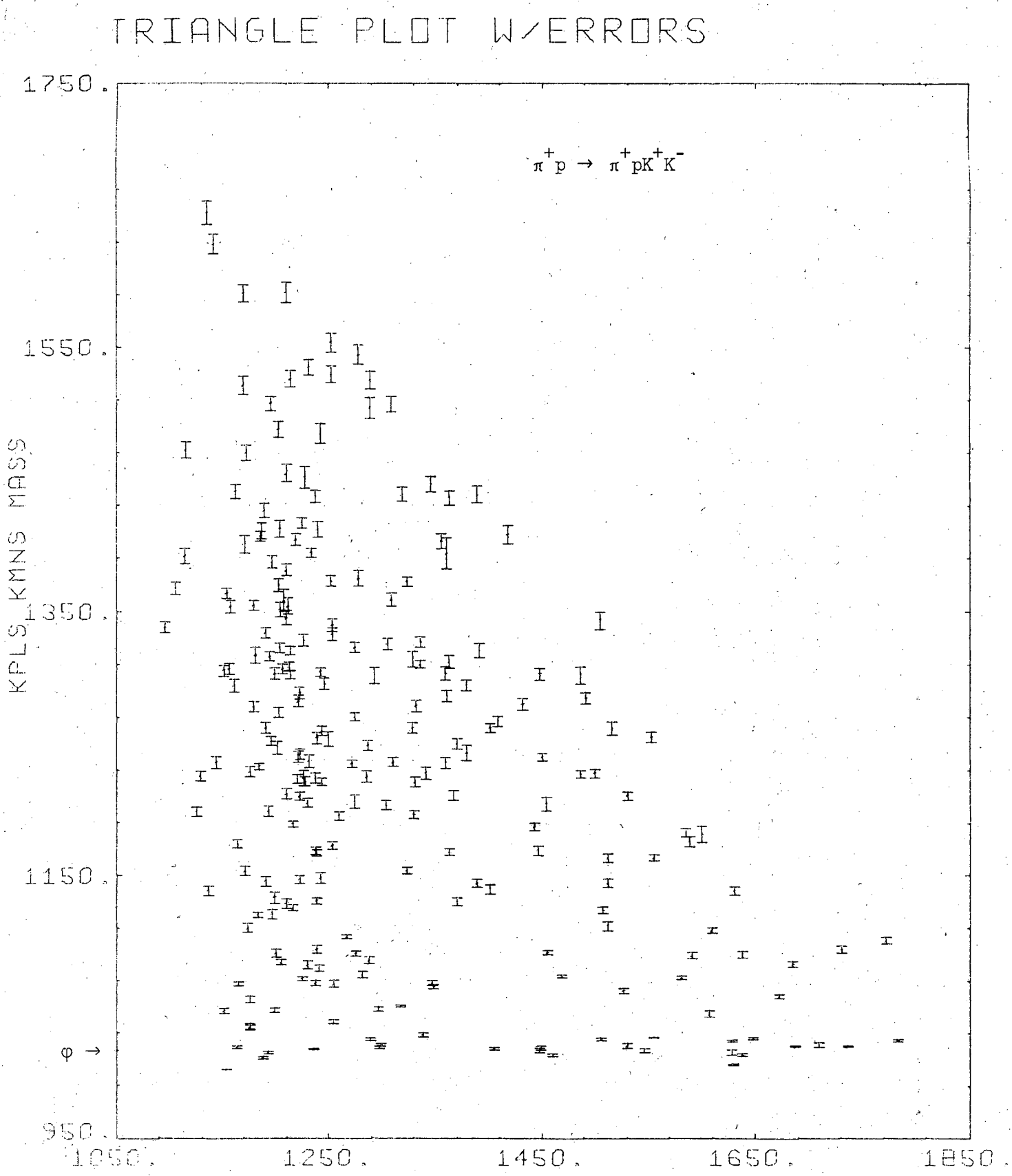
TRIANGLE PLOT W/ERRORS
$\pi^+ p \rightarrow \pi^+ p K^+ K^-$
1750.
1550.
1350.
1150.
φ →
950.
1050.
1250.
1450.
1650.
1850.
KPLS KMNS MASS
P PIPLS MASS

Fig. 1

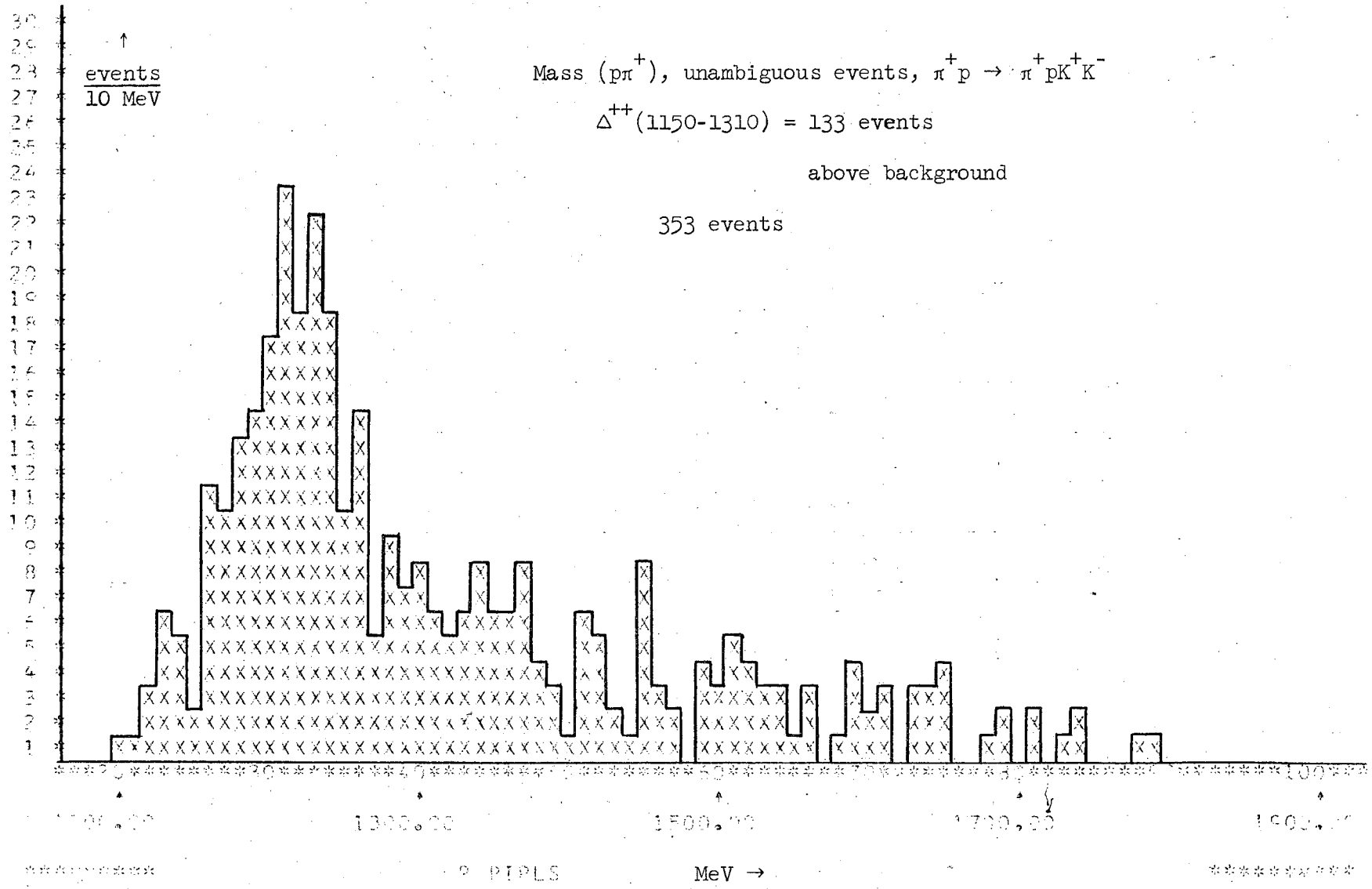
events
10 MeV
Mass ($p\pi^+$), unambiguous events, $\pi^+p \rightarrow \pi^+pK^+K^-$
Δ^{++}(1150-1310) = 133 events
above background
353 events
1300.00
1500.00
1700.00
MeV →

Fig. 2

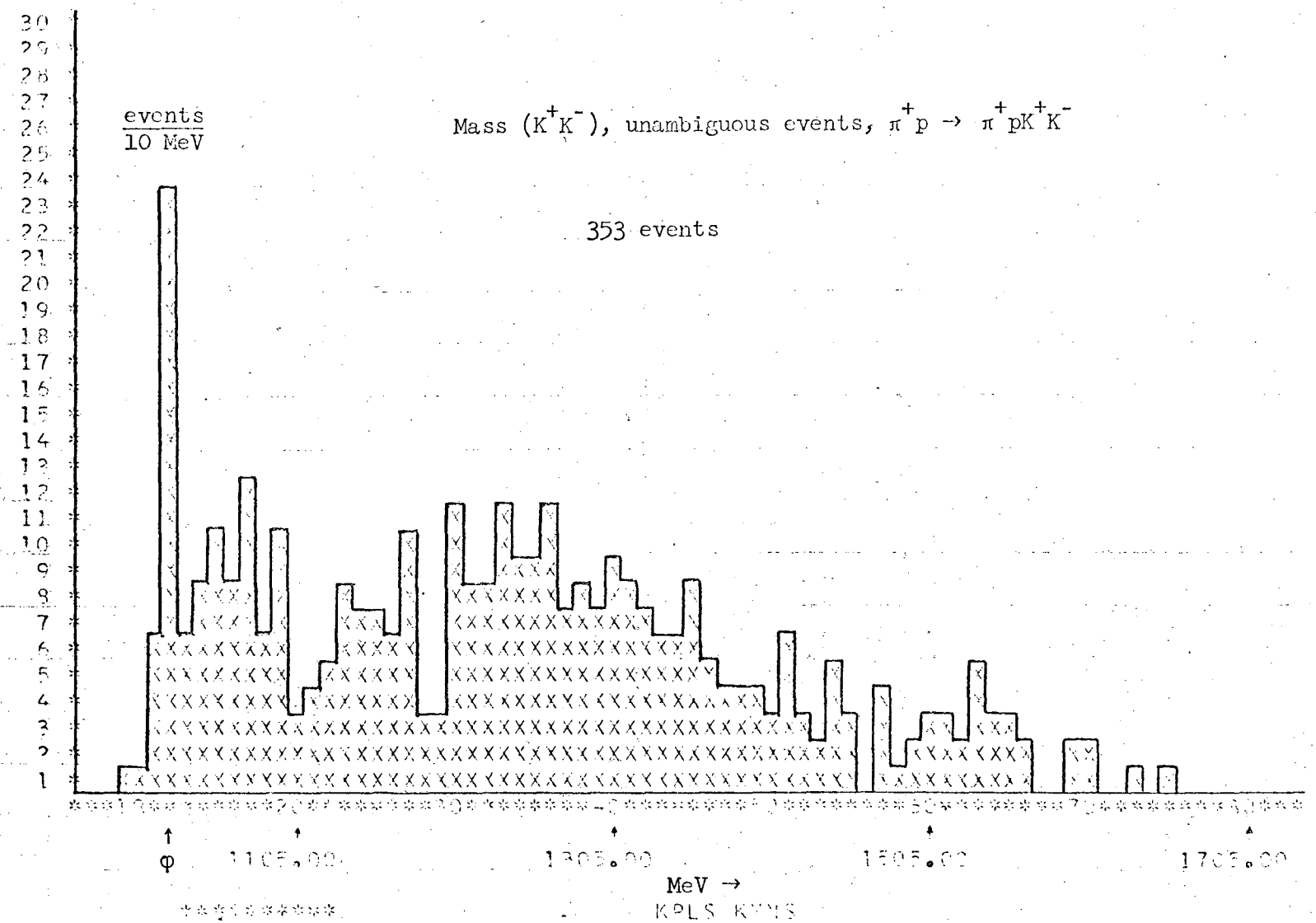
events
10 MeV
Mass (K^+K^-), unambiguous events, $\pi^+p \rightarrow \pi^+pK^+K^-$
353 events
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
φ
1105.00
1305.00
1505.00
1705.00
MeV →

Fig. 3

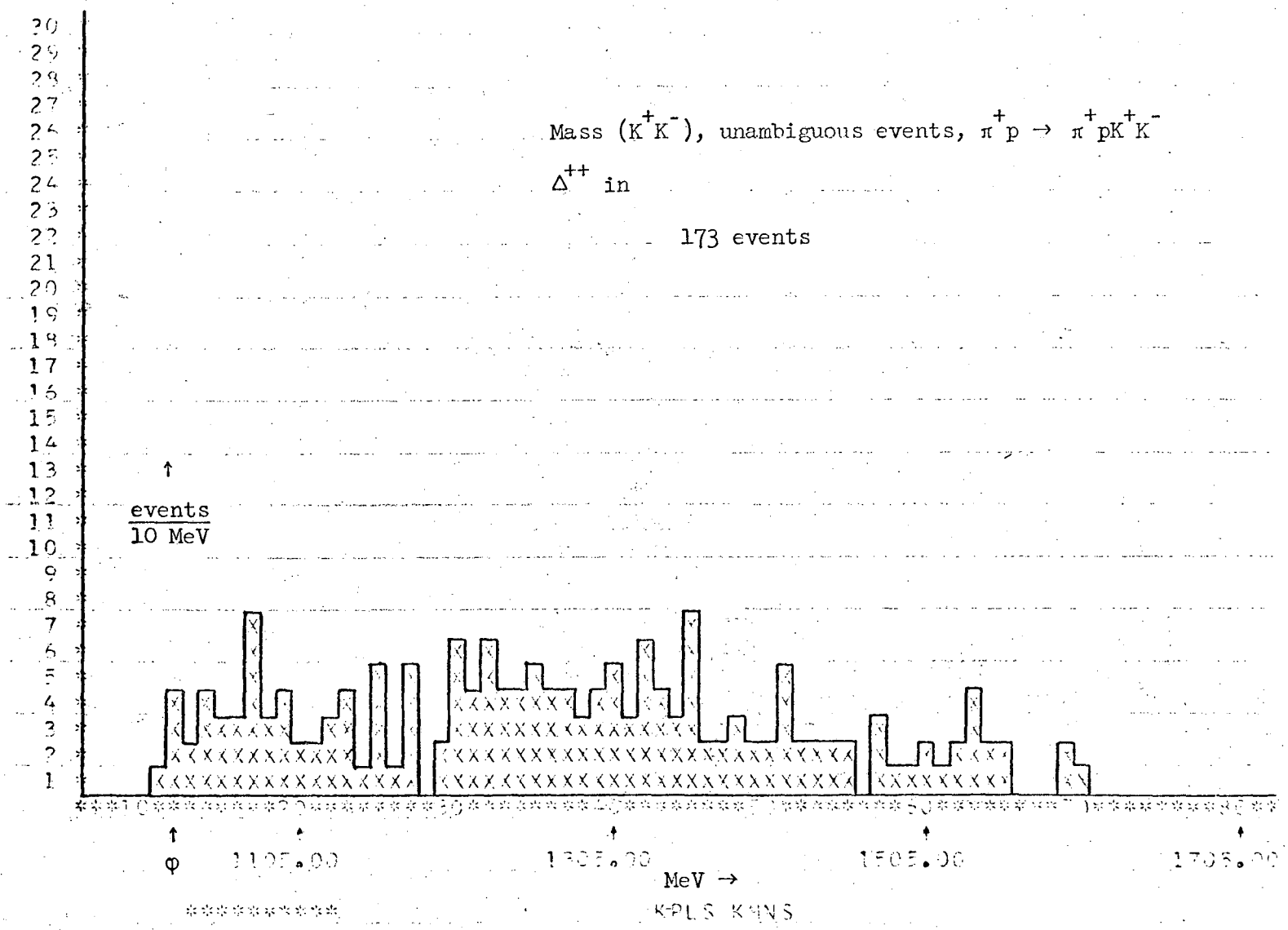
Mass (K^+K^-), unambiguous events, $\pi^+p \rightarrow \pi^+pK^+K^-$
Δ^{++} in
173 events
events / 10 MeV
φ
1105.00
1305.00
1505.00
1705.00
MeV →

Fig. 4

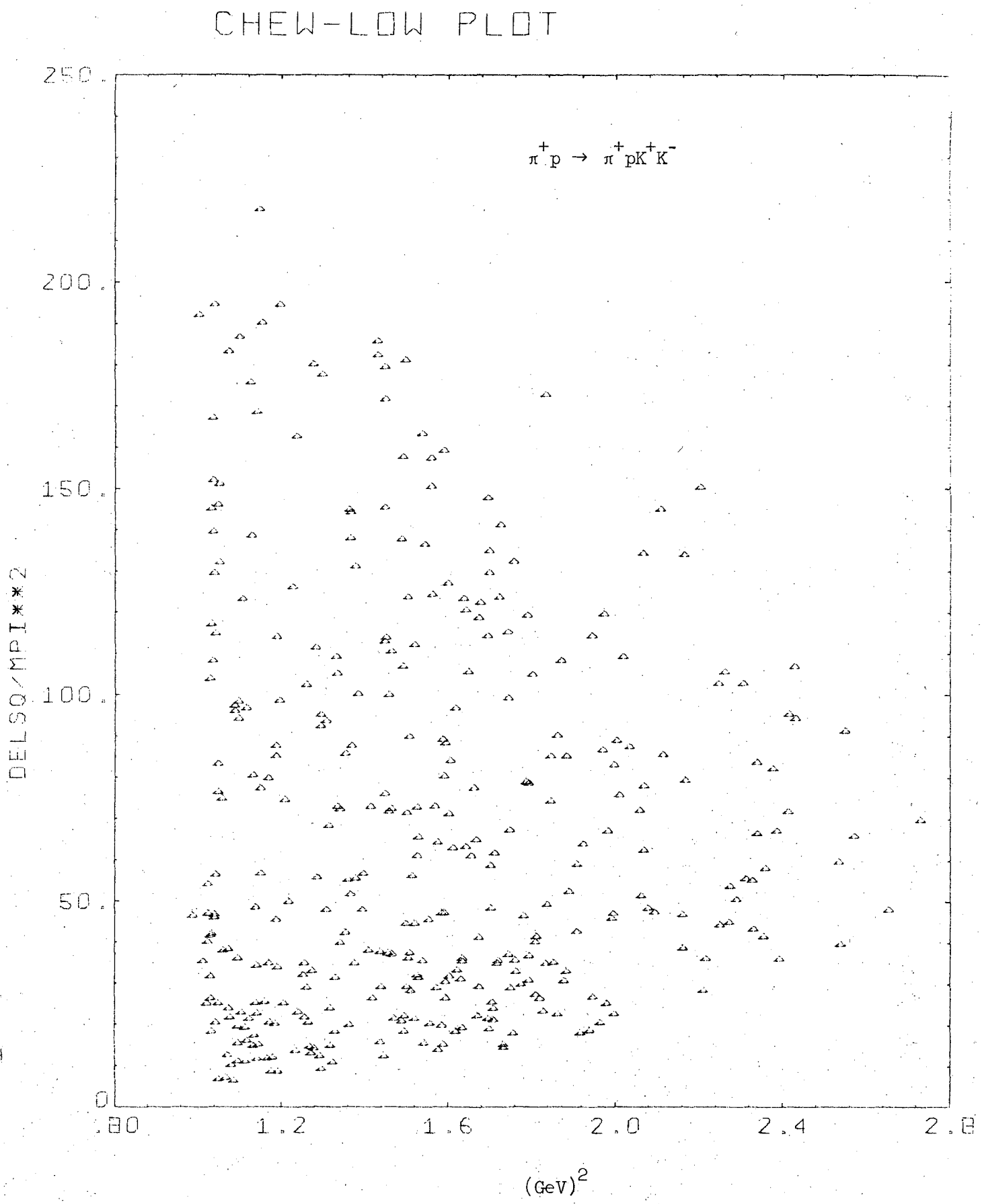
CHEW-LOW PLOT
$\pi^+ p \rightarrow \pi^+ p K^+ K^-$
250.
200.
150.
100.
50.
0
DELSQ/MPI**2
.80
1.2
1.6
2.0
2.4
2.8
$(GeV)^2$
K+ K- MASS SQUARED

Fig. 5

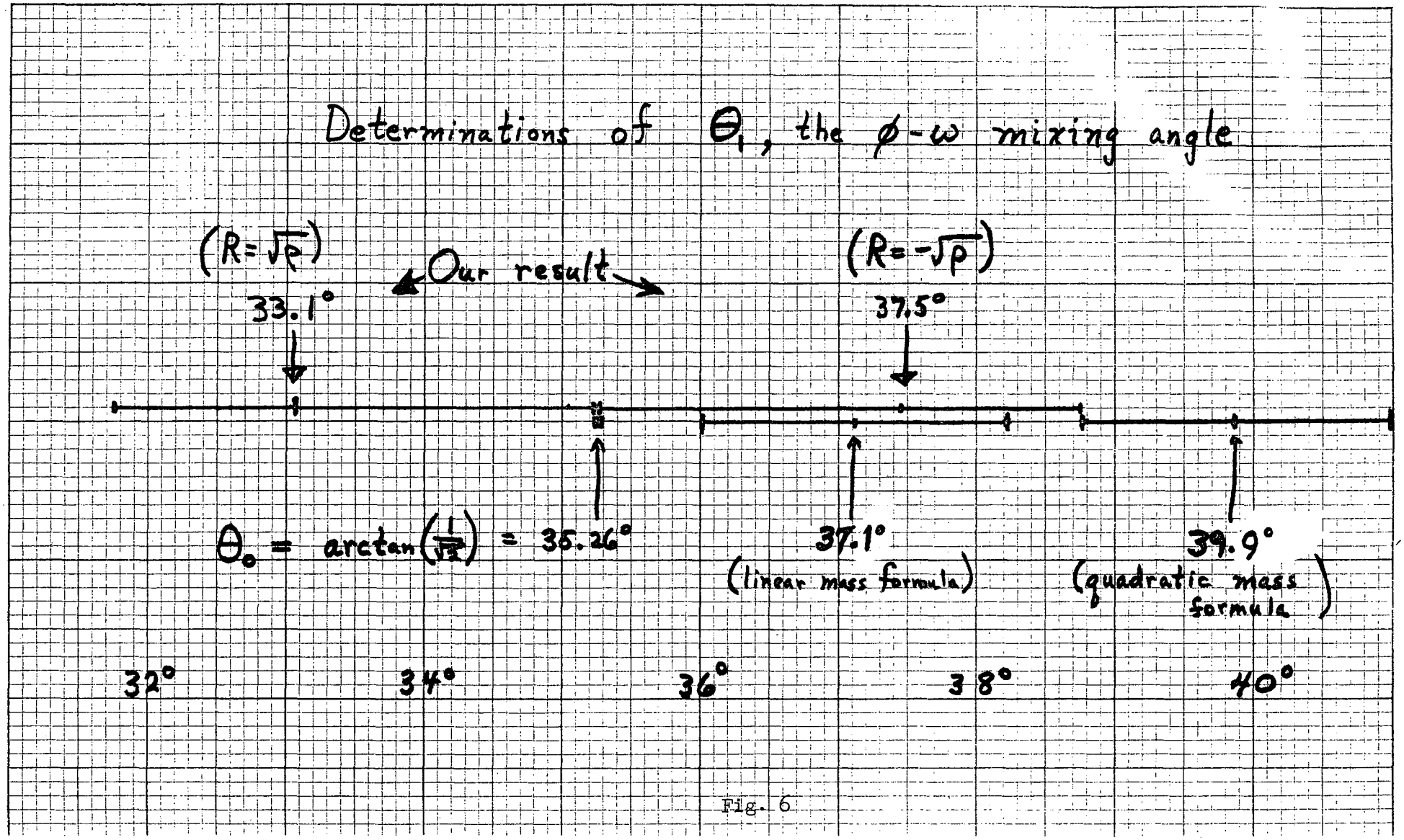
Determinations of θ_1, the ϕ-ω mixing angle
$(R=\sqrt{\rho})$
33.1°
Our result
$(R=-\sqrt{\rho})$
37.5°
$\theta_0 = \arctan\left(\frac{1}{\sqrt{2}}\right) = 35.26°$
37.1°
(linear mass formula)
39.9°
(quadratic mass formula)
32°
34°
36°
38°
40°

Fig. 6

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