Ichigaya, Tokyo, Feb.25, 2003

Experimental Search for 1^{-+} Meson

→ Indication of 1^{-+} Meson

T. Tsuru (KEK)

1. Why is 1^{-+} meson important and interesting?
2. History and mini-review
3. What is 1^{-+}?

1. Why is 1^{-+} meson important and interesting?

L-S coupling scheme of SU(3) qqbar:

excellently successful in the long past years.

but some J^{pc} missing 0^{+-}, 1^{-+}, 2^{+-}, 3^{-+} etc.

and 0^{--}.

If even one of them is found, it is really a non-qqbar SU(3) flavor state.

There is no ambiguity in the meaning of non-qqbar exotic.

1^{-+}

2. History of search for 1^{-+} mesons

2-1 $\pi_1(1400)$

challenging but difficult

- First indication in 1988: GAMS collab., D.Alde et al., PL B205 (1988) 397

  $\pi_1(1400)$ in $\eta\pi^0$ of $\pi^- p \to \eta\pi^0 n$ at 100 GeV/c (CEX reaction)

  Mass=1406+-20 MeV, Width=180+-30 MeV

- KEK-E179, H.Aoyagi et al., PL B314 (1993) 246.

  $\pi_1(1400)$ in $\eta\pi^-$ of $\pi^- p \to \eta\pi^- p$ at 6.3 GeV/c (Diffractive Reaction)

  Mass=1323+-4.6 MeV, Width=143.2+-12.5 MeV

- VES $\pi^- N \to \eta\pi^- N$ 37 GeV/c 1993 PL B 313 ('93) 276

- BNL E752 in 1997; D.Thompson et al., PRL 79 (1997) 1630

  S.Chung et al., PR D60 (1999) 092001.

  $\pi_1(1400)$ in $\eta\pi^-$ of $\pi^- p \to \eta\pi^- p$ at 18G eV/c

  Mass=1370+-16 MeV Width=385+-40 MeV

- Crystal Barrel in 1998; A.Abele et al., PL 423 (1998) 125.

  A.Abele et al., PL 446 (1999) 349

  $\pi_1(1400)$ in $\eta\pi$ in pbard $\to \pi^- \pi^0 \eta$ p_{spec} at LEAR

  Mass=1400+-20+-20 MeV Width= 310+-50 MeV

  $\pi_1(1400)$ in $\eta\pi^0$ in pbarp $\to \pi^0\pi^0\eta$ at LEAR

  Mass= 1360+-25 MeV Width= 220+- 90 MeV

PL B314('88) 246

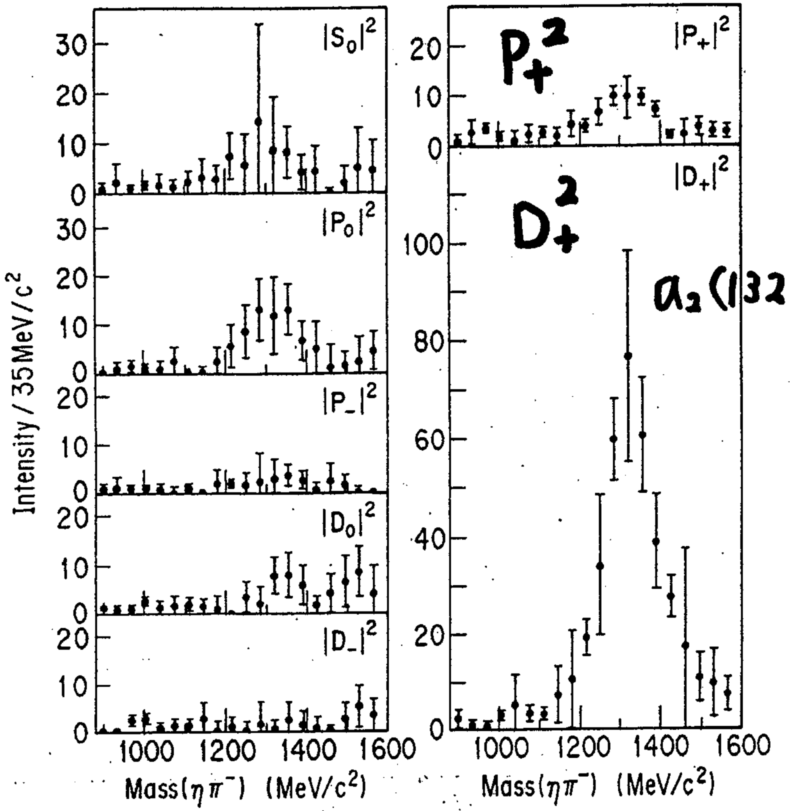


Fig. 10. Intensity distributions of partial waves. The partial waves are indicated in the figure. The backgrounds estimated by the events in the η control regions are subtracted.

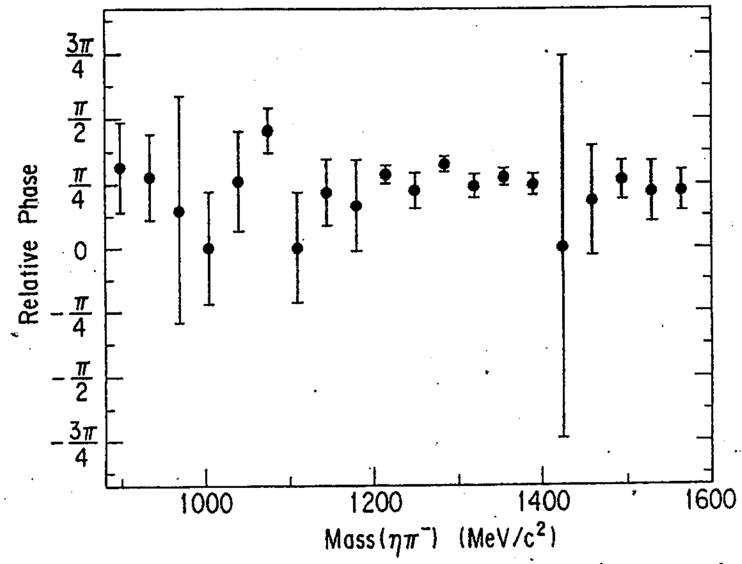


Fig. 11. Phase variation of the D_+ wave relative to the P_+ wave.

Phase : P_+ vs D_+

($a_2(1320)$) 2^{++}

$\pi^- p \to \eta \pi^- p$ 6.3 GeV/c

KEK-E179 1993

$M = 1323 \pm 4.6$ MeV

$\Gamma = 143 \pm 12.5$ MeV

$\pi^- N \to \eta \pi^- N$ 37 GeV/c
VES 1993

PL B313 (93) 276

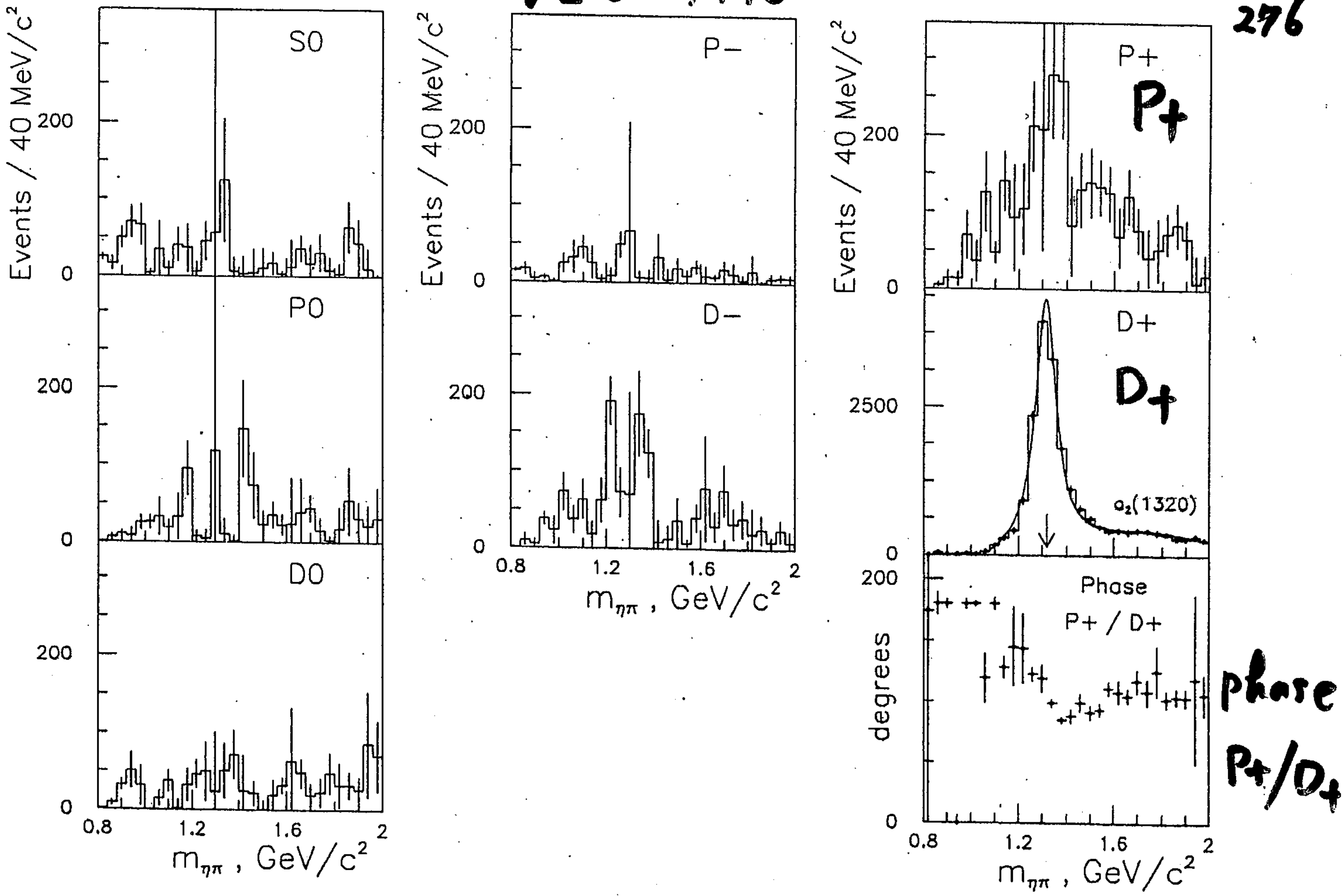


Fig. 3. Results of the partial-wave analysis of the $\eta\pi^-$ system.

$\pi p \to \eta \pi p$ 18 GeV/c

BNL E752 1997

PR D60 ('99) 092001

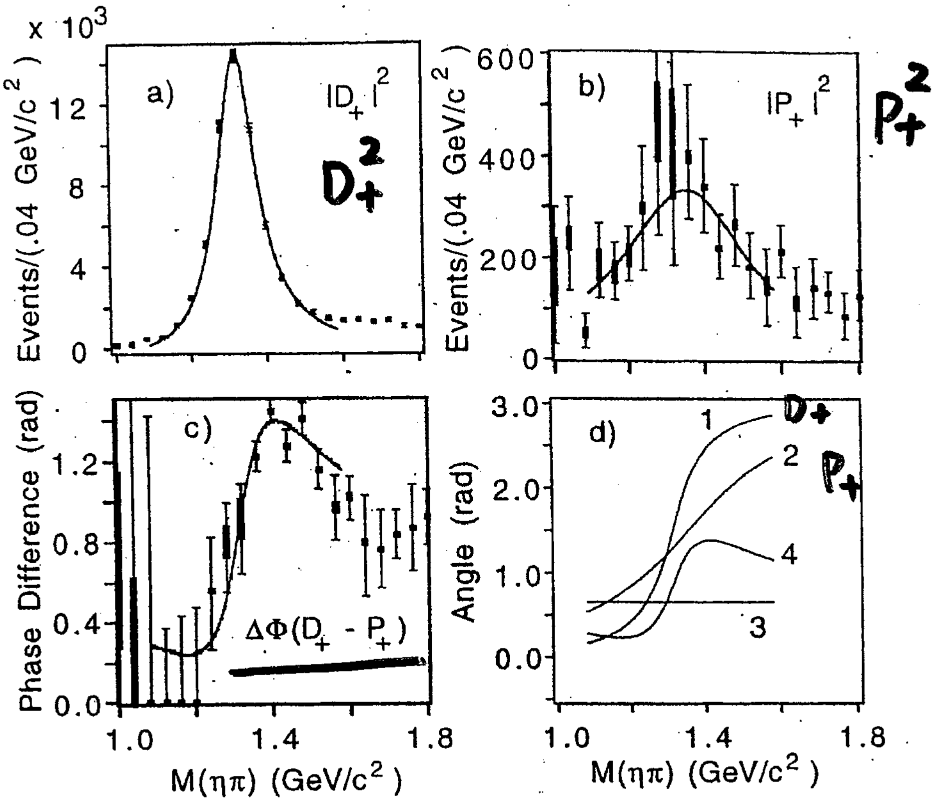


FIG. 17. Results of the partial wave amplitude analysis. Shown are (a) the fitted intensity distributions for the D_+ and (b) the P_+ partial waves, and (c) their phase difference $\Delta\Phi$. The range of values for the eight ambiguous solutions is shown by the central bar and the extent of the maximum error is shown by the error bars. Also shown as curves in (a), (b), and (c) are the results of the mass dependent analysis described in the text. The lines in (d) correspond to (1) the fitted D_+ Breit-Wigner phase, (2) the fitted P_+ Breit-Wigner phase, (3) the fitted relative production phase ϕ, and (4) the overall phase difference $\Delta\Phi$.

$M = 1370 \pm 16$ MeV

$\Gamma = 385 \pm 40$ MeV

$\bar{p}\,d \to \pi^- \pi^0 \eta\, p_{spec.}$
Xtal Barrel
1998

PL B423 (1998) 175

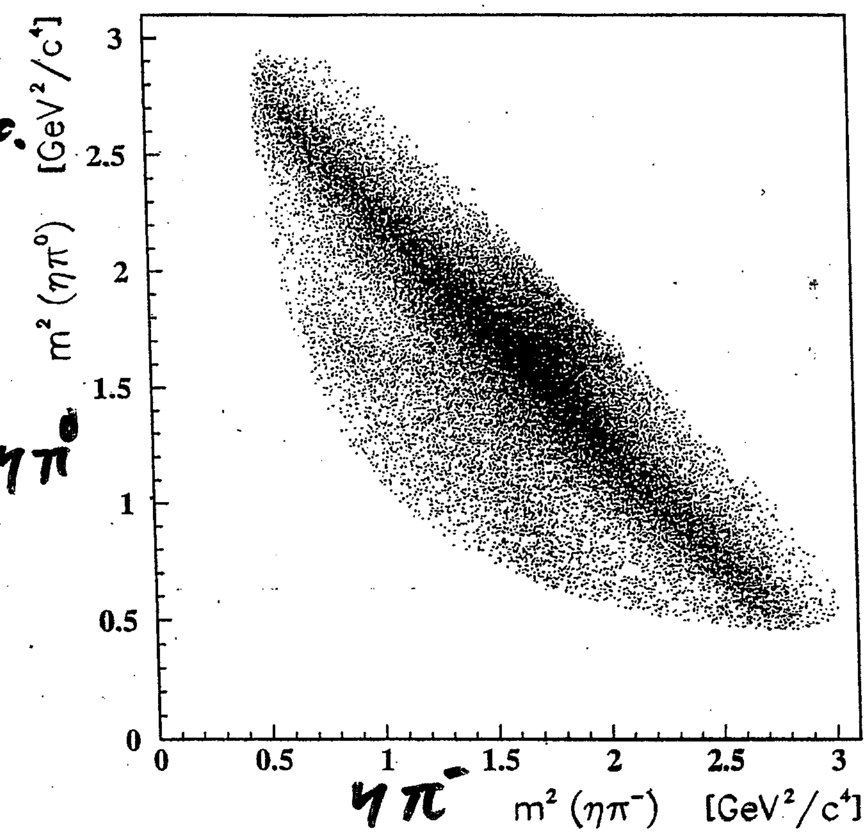
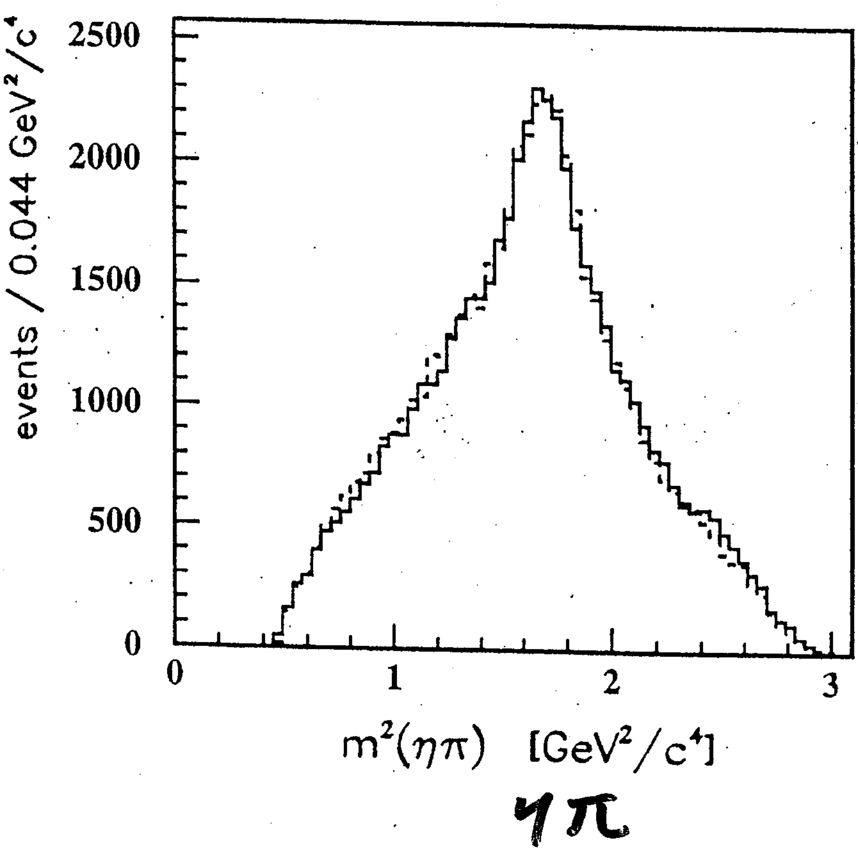


Fig. 1. Dalitz plot (not acceptance corrected) of the final sample of $\pi^-\pi^0\eta$ events from the annihilation reaction $\bar{p}d \to \pi^-\pi^0\eta p_{spectator}$ with $P(p_{spectator}) < 100$ MeV/c.

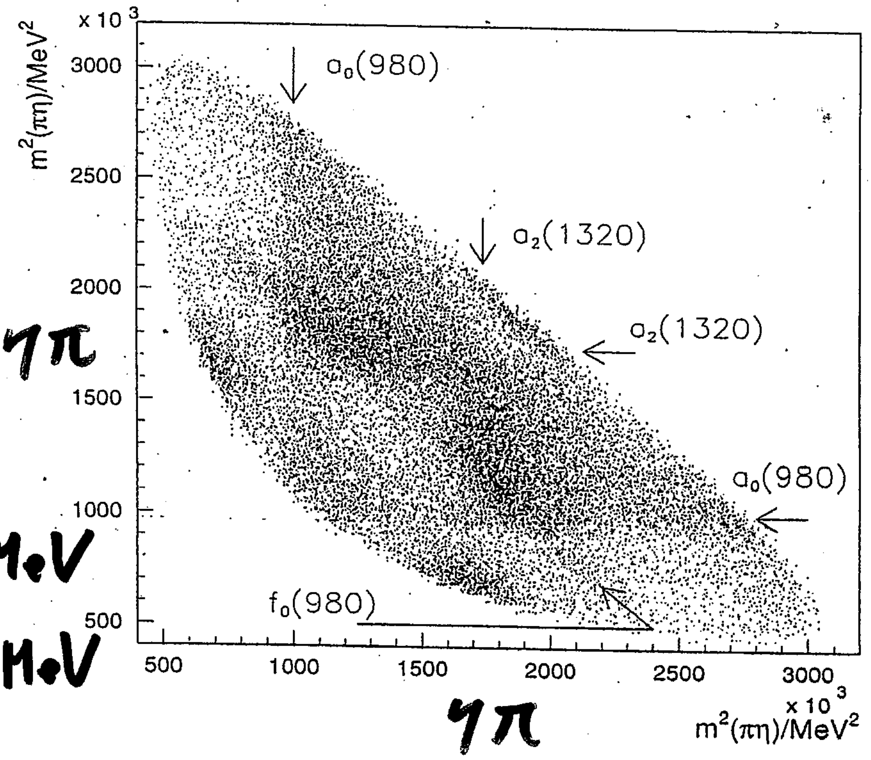
M = 1400 ± 20 MeV

Γ = 310 ± 50 MeV



$\bar{p}p \to \pi^0\pi^0\eta$ PL B 446 (99) 349

Xtal Barrel 1999



$M = 1360 \pm 25$ MeV

$\Gamma = 220 \pm 90$ MeV

Fig. 1. Dalitz plot of $\bar{p}p$ annihilations at rest into $\pi^0\pi^0\eta$ for antiprotons stopping in gaseous hydrogen at 12 atm (2 entries per event).

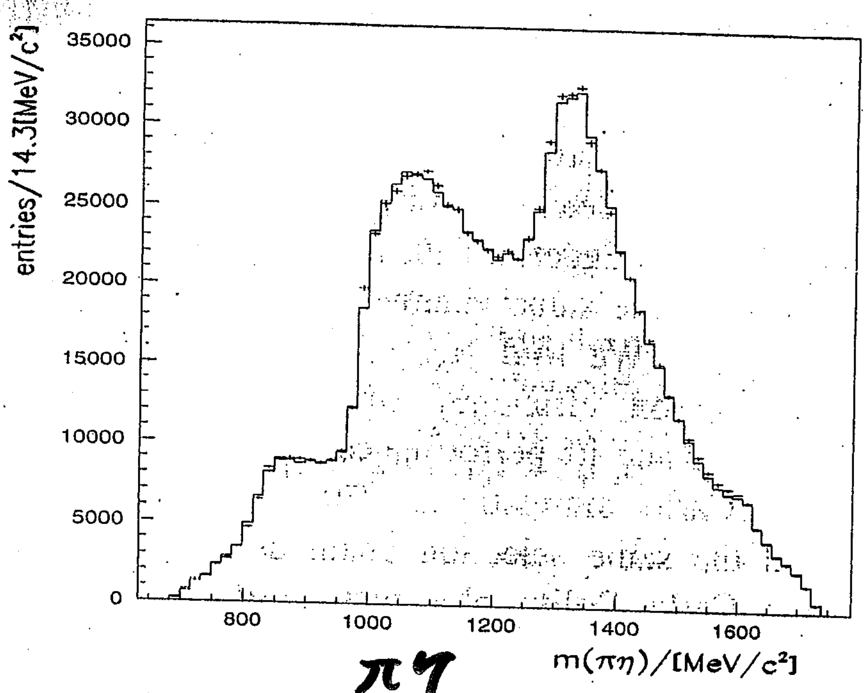


Fig. 2. The $(\eta\pi)$ mass distribution for $\bar{p}p \to \pi^0\pi^0\eta$ for data from gaseous hydrogen. The shaded area represents the fit.

2. History of 1^{-+} mesons

2-2 $\pi_1(1600)$

Earlier report VES 1992; Yu.Gouz et al.,Dallas HEP92 p572.

$\pi_1(1600)$ in X^- of $\pi^- N \to X^- N$ at 37 GeV/c

$X = \eta'\pi^-$, $\rho\pi$, $b_1(1235)\,\pi$, not $\eta\pi^-$

VES 1993; D.Beladidze et al., PL B313 (1993) 276.

$\pi_1(1600)$ in $\eta'\pi^-$ of $\pi^- N \to \eta\pi^-$ and $\eta'\pi^-$ N at 37 GeV/c

BNL E852 in 1998; G.Adams et al., PRL B81 (1998) 5760

$\pi_1(1600)$ in $\rho\pi^-$ of $\pi^- p \to \pi^+\pi^-\pi^-$ p at 18 GeV/c

Mass=1593+-8 MeV, Width= 168+-20 MeV

E.Ivanov et al., PRL 86 (2001) 3977.

$\pi_1(1600)$ in $\eta'\pi^-$ of $\pi^- p \to \eta'\pi^-$ p at 18 GeV/c

Mass=1597+-10 MeV, Width=340+-40 MeV

π⁻N → η π⁻ N 37 GeV/c PL B313 ('93) 276

VES 1993

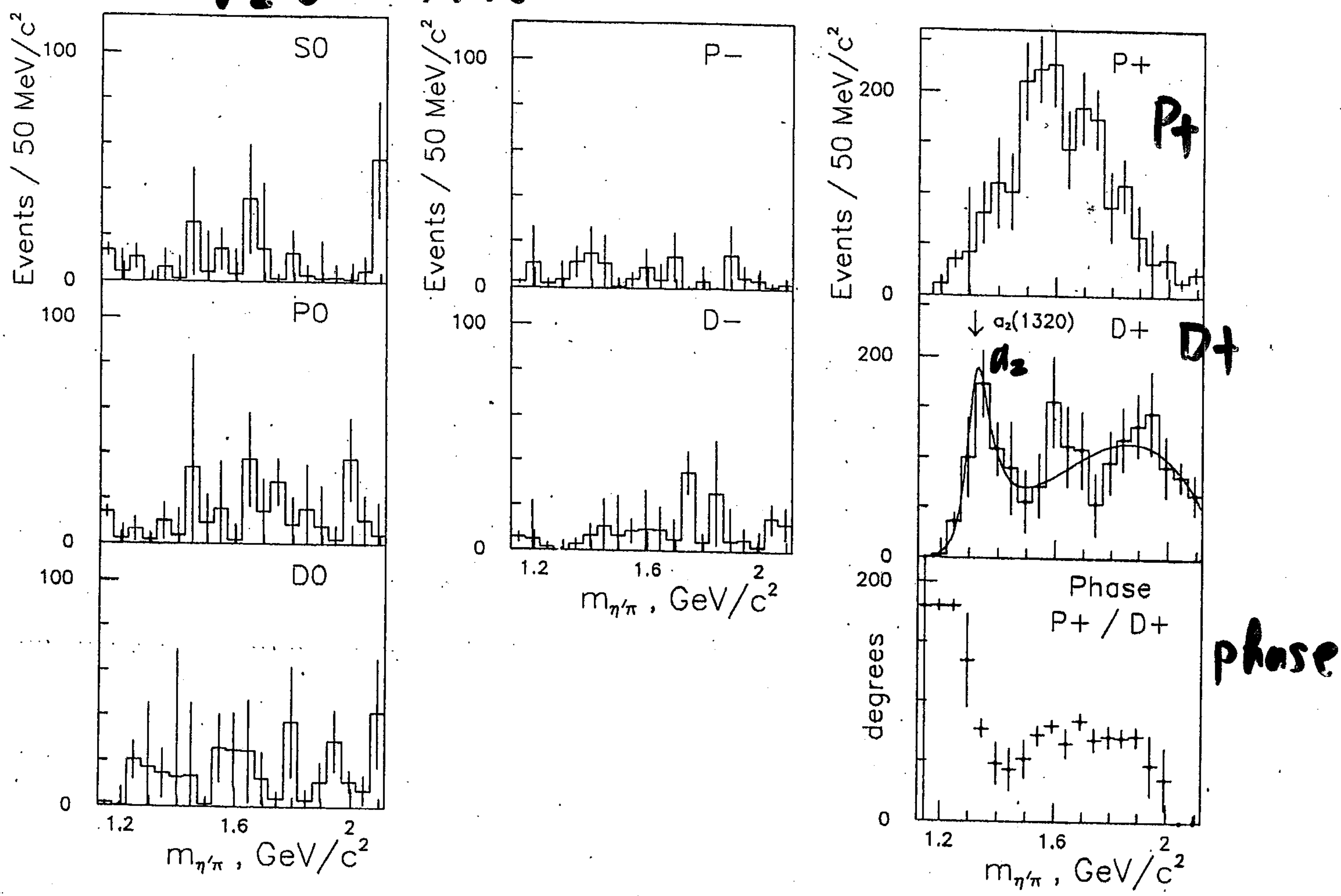


Fig. 4. Results of the partial-wave analysis of the $\eta'\pi^-$ system.

η'π

π⁻ p → π π π p 18 GeV/c

PRL 81 ('98) 5760

BLN E852 1998

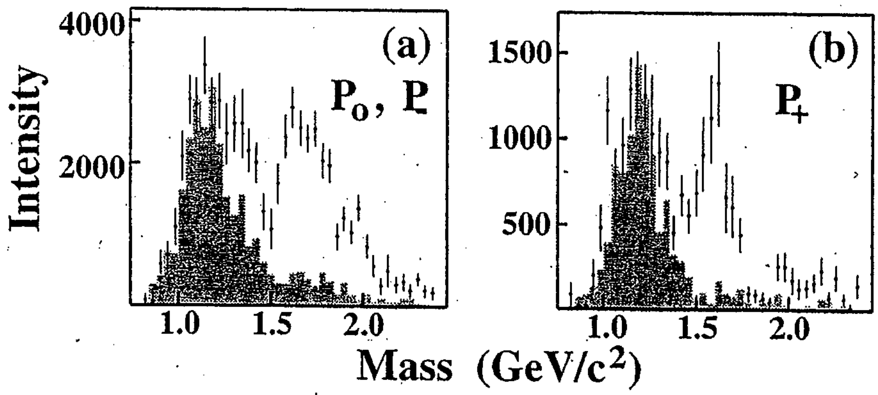


FIG. 3. Wave intensities of the $1^{-+}[\rho(770)]P$ exotic waves: (a) the $M^{\epsilon} = 0^-$ and 1^- waves combined; (b) the $M^{\epsilon} = 1^+$ wave. The PWA fit to the data is shown as the points with error bars and the shaded histograms show estimated contributions from all nonexotic waves due to leakage.

M = 1593 ± 8 MeV

Γ = 168 ± 20 MeV

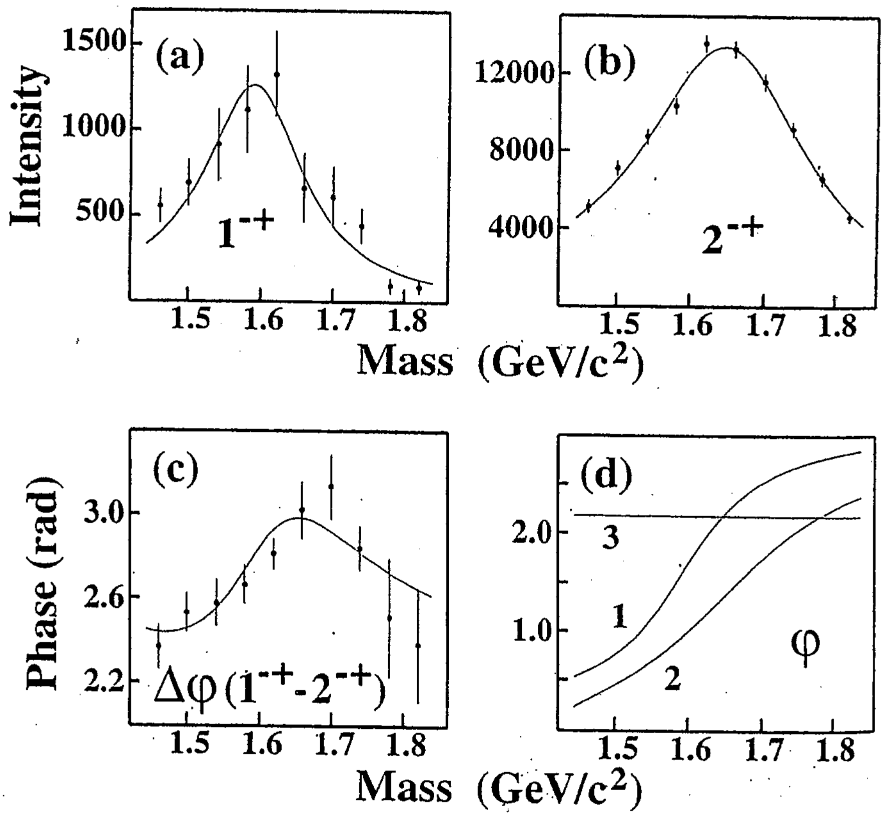


FIG. 5. A coupled mass-dependent Breit-Wigner fit of the $1^{-+}[\rho(770)]P1^+$ and $2^{-+}[f_2(1270)]S0^+$ waves: (a) $1^{-+}[\rho(770)]P1^+$ wave intensity; (b) $2^{-+}[f_2(1270)]S0^+$ wave intensity; (c) phase difference between the $1^{-+}[\rho(770)]P1^+$ and $2^{-+}[f_2(1270)]S0^+$ waves; (d) phase motion of the $1^{-+}[\rho(770)]P1^+$ wave (1), $2^{-+}[f_2(1270)]S0^+$ wave (2), and the production phase between them (3).

3. What are 1-+ mesons? $\pi_1(1400)$, $\pi_1(1600)$

Glueballs? Never, due to isovectors

Hybrids? Possible but too low

Lattice calculation: about 1.9 GeV

flux tube model: about 1.9 GeV

Four quark states? (qqqbarqbar?) possible

$\pi_1(1400)$: four quark state?

$\pi_1(1600)$: hybrid? or four quark state?

Another possibility:

Non-relativisitic L-S coupling scheme: missing nonets.

Relativistic view of chiral symmetry: extra nonets appear.

One more 0++(σ ,κ etc.) and 1++(a_1^{χ} etc.) can exist.

1-+ is also possible. $\pi_1(1400)$ could be. Need study.

(S. Ishida's talk Feb. 24)

$\pi_1(1600)$ also possible.