Coupled-channel analysis of a $J^{PC} = 1^{-+}$ exotic meson

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- Introduction to K-matrix formalism
- Our model
- Results

This work was done by R. Longacre using his own formalism.

S. U. Chung pursuaded him to recast his results into a form known as 'P-vector approach with K-matrix formalism.'

See the following references for a discussion on the P-vector approach:

The K-matrix Formalism for overlapping resonances

I. J. R. Aitchison,
NP **A189**, 417 (1972)

Partial-wave analysis in K-matrix formalism

S. U. Chung *et al.*,
Annalen der Physik, **4**, 404 (1995)

P-vector approach

Consider a process in which a resonance is coupled to two channels:

$$\text{Channel } 1 = \eta\pi$$
$$\text{Channel } 2 = f_1(1285)\pi$$

so that

$$P = \begin{pmatrix} P_1 \\ P_2 \end{pmatrix} \qquad \text{for production—complex}$$

$$F = \begin{pmatrix} F_1 \\ F_2 \end{pmatrix} \qquad \text{after final-state interaction}$$

Assume a real 2×2 K-matrix,i.e.

$$T = \begin{pmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{pmatrix}$$

where T_{ij} are real and symmetric.
Then,

$$\boxed{F = (I - i\,K)^{-1}\,P}$$

$J^{PC} = 1^{-+}$ Exotic Hybrid

Assume that there exists a $J^{PC} = 1^{-+}$ state with mass 1.90 GeV and width 550 MeV, coupling to $\eta\pi$ and $f_1(1285)\pi$ with branching ratios 5% and 95%, respectively. Then,

$$w_{_H} = 1.90 \text{ GeV}$$
$$\Gamma_{_H} = 550 \text{ MeV}$$

and $\Gamma_{_H} = \Gamma_1 + \Gamma_2$ where

$$\begin{array}{lrrll} \Gamma_1 & = & 25 & \text{MeV} \quad \text{for} & \eta\pi \\ \Gamma_2 & = & 525 & \text{MeV} \quad \text{for} & f_1(1285)\pi \end{array}$$

Let w be the effective mass, and

$$\Gamma_1 = \gamma_1^2 \, \Gamma_{_H} \, B^2(q_1) \, \rho(q_1)$$
$$\Gamma_2 = \gamma_2^2 \, \Gamma_{_H} \, \rho(q_2)$$

where q_i is the breakup momentum in channel i, and

$$\rho(q_i) = \frac{2q_i}{w}$$

is the phase-space factor for channel i.
$B(q)$ is the P-wave angular-momentum barrier factor given by

$$B(q) = \left[\frac{(q/q_r)^2}{1 + (q/q_r)^2}\right]^{1/2}$$

where $q_r = 0.1973$ GeV/c.

The elements of the K-matrix are

$$K_{11} = \frac{w_{_H}\Gamma_1}{w_{_H}^2 - w^2} + \frac{w_{_H}\Gamma_b}{D_b}$$
$$K_{22} = \frac{w_{_H}\Gamma_2}{w_{_H}^2 - w^2}$$
$$K_{12} = K_{21} = \frac{w_{_H}\sqrt{\Gamma_1\Gamma_2}}{w_{_H}^2 - w^2}$$

where D_b gives the strength of the background term and Γ_b its mass dependence

$$\Gamma_b = \gamma_b^2\,\Gamma_{_H}\,B^2(q_1)\,\rho(q_1)$$

for the $\eta\pi$ channel (channel 1).
The production amplitudes are given by

$$P_1 = \left[\gamma_1\left(\frac{w_{_H}\Gamma_{_H}}{w_{_H}^2 - w^2}\right) V_{_H} + \gamma_b\left(\frac{w_{_H}\Gamma_{_H}}{D_b}\right) V_b\right] B(q_1)$$
$$P_2 = \gamma_2\left(\frac{w_{_H}\Gamma_{_H}}{w_{_H}^2 - w^2}\right) V_{_H}$$

where the complex parameters $V_{_H}$ and V_b govern production of the hybrid meson and its background.

Results of fit

From the assumed values of the partial widths,

$$\gamma_1 = 1.051 \qquad \text{and} \qquad \gamma_2 = 0.293$$

Fit to the observed P-wave $\eta\pi^-$ and its phase[a] relative to the $a_2(1320)$ (assumed to behave as a standard D-wave Breit-Wigner resonance) gives

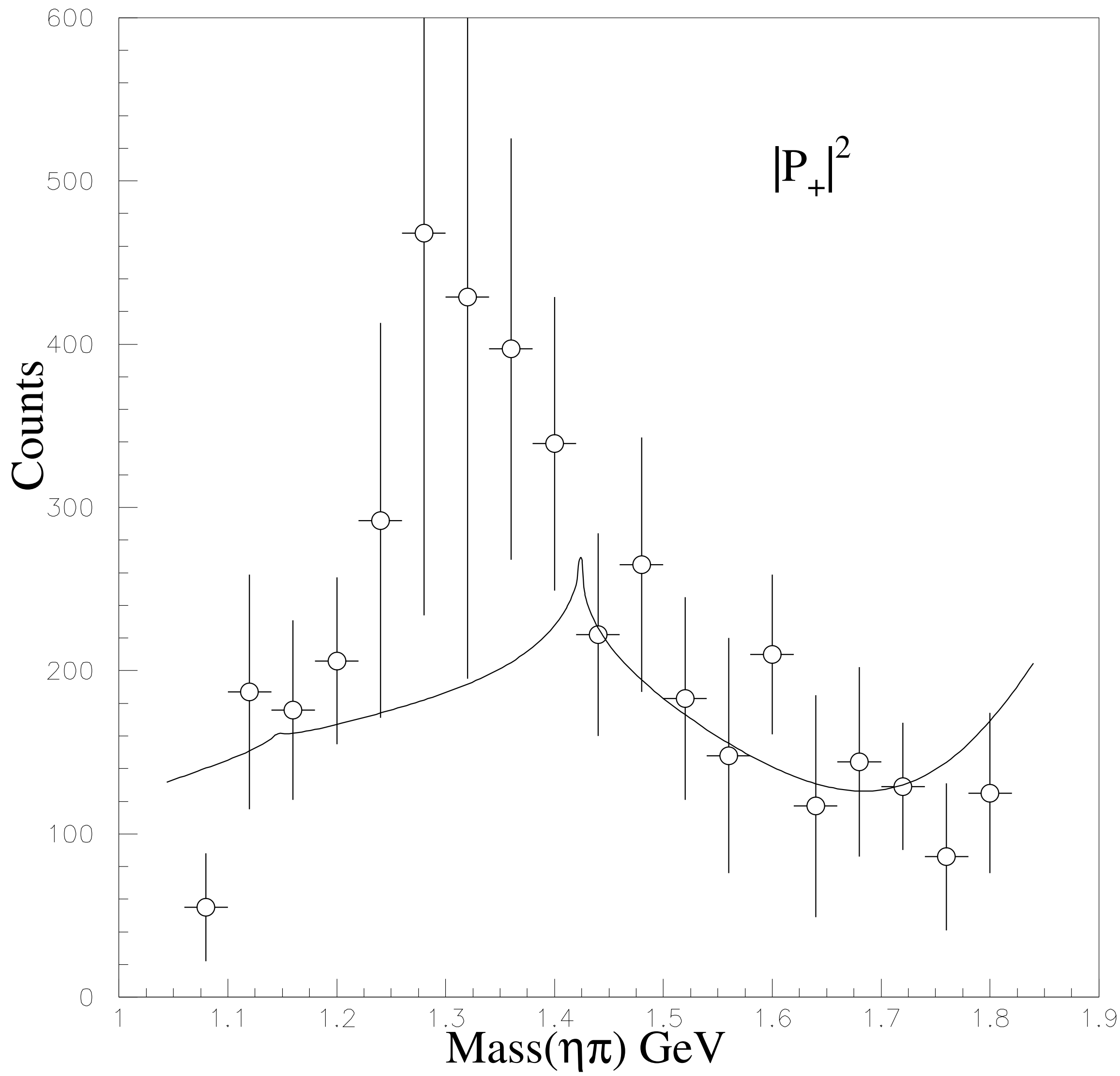
$$\begin{aligned} V_{_H} &= (-173.0, 66.61) \\ \gamma_b &= 0.042 \\ D_b &= 0.645 \quad \text{GeV}^2 \\ V_b &= (298.7, 234.6) \end{aligned}$$

[a] D. R. Thompson *et al.*,
Phys. Rev. Lett. **79**, 1630 (1997)

Two-channel K-matrix fit

$\pi^- p \to \pi^- \eta\ p$

$\to \pi^- f_1(1285)\ p$ at 18 GeV/c



Two-channel K-matrix fit

$\pi^- p \to \pi^- \eta \; p$

$\quad \to \pi^- f_1(1285) \; p$ at 18 GeV/c