JPAC recent results: Determination of the lightest hybrid meson

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A. Jackura, M. Mikhasenko, A. Pilloni et al. (JPAC & COMPASS), PLB779, 464-472

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Introduction

- Motivation
- Data

Method

Coupled channel

Future prospects
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Students, Postdocs, Faculties
JPAC: theory, phenomenology and analysis tools in support of experimental data from JLab12 and other accelerator laboratories.

Contribute to education of new generation of practitioners in strong interactions.
Single meson production


SDMEs of vector production


Global analysis

J. Nys et al. (JPAC), arXiv:1806.01891
\( \tau \rightarrow 3\pi \nu \)

M. Mikhasenko et al.

[JPAC], In Preparation

\( Z_c(3900) \)

A. Pilloni et al. [JPAC],

Phys. Lett. B 772

(2017)200

\( P_c(4450) \)

A. Hiller Blin et al.

[JPAC], Phys. Rev. D

94 (2016)034002
Motivation

- In this talk: Recent analysis on spectroscopy
- Ordinary hadrons → first part of the talk
- Not so ordinary
- Hybrids: Ongoing analysis
Table of Content

1 Introduction
   • Motivation
   • Data

2 Method

3 Coupled channel

4 Future prospects
Data: COMPASS experiment

- $E_{Beam} = 190\text{GeV}$ ⇒ Peripheral production
- Dominated by $J^{PC} = 2^{++}$ ⇒ Ordinary meson.

- Asymmetry $\rightarrow$ odd (exotic) waves.
- Dominated by $J^{PC} = 1^{-+}$ ⇒ non $q\bar{q}$ quantum numbers.
Clear $a_2(1320)$ decaying into $\eta\pi$ and $\eta'\pi$?

Is there a clear $a_2'(1700)$? What are its parameters?
Status

- $\pi_1(1400)$ decaying into $\eta\pi$?

- Different $\pi_1(1600)$ decaying into $\eta'\pi$?
Partial waves

- Coupling to $\eta\pi$ much smaller than $\eta'\pi \Rightarrow$ Hybrid nature?
- Ordinary mesons have similar couplings.
- Data looks suspicious above 2 GeV.

(a) $P$-wave, $L = 1$
(b) $D$-wave, $L = 2$
Table of Content

1 Introduction
   - Motivation
   - Data

2 Method

3 Coupled channel

4 Future prospects
Method

- Peripheral production $\Rightarrow$ factorization of the pomeron
  $\Rightarrow Ima(s) = \rho(s)t^*(s)a(s)$.

- Amplitude built around $t(s) = \frac{N(s)}{D(s)}$ method
  $\Rightarrow a(s) = p^2 q \frac{n(s)}{D(s)}$.

- They are smooth polynomials $n(s) = \sum_j a_j w^j(s)$, where
  $w(s) = \frac{s}{s + s_0}$.
Method

- N(s) and n(s) are process dependent, they have only left hand cuts.
- D(s) has a right hand cut, altogether t(s) has the correct analytic structure.

- By adding this discontinuity over the RHC one could go to the direct continuous Riemann sheet.
Single channel

A. Jackura, M. Mikhasenko, A. Pilloni et al. (JPAC & COMPASS), PLB779, 464-472

\[ Imt(s) = \rho(s)|t(s)|^2 \Rightarrow ImD(s) = -\rho(s)N(s), \] so that

\[ D(s) = D_0(s) - \frac{s}{\pi} \int_{sth}^{\infty} ds' \frac{\rho(s')N(s')}{s'(s' - s)}, \]

where \( D_0(s) = c_0 - c_1 s - \frac{c_2}{c_3 - s} \rightarrow \text{CDD poles}. \)

And \( \rho(s)N(s) = g \frac{\lambda^{(2l+1)/2}(s, m_{\pi}^2, m_{\eta}^2)}{(s + s_R)^{2l+3}}. \)
Single channel

- 12 parameters, $\chi^2 \approx 2$.
- Good description of both peaks, the residuals of the fits follow a Gaussian distribution.
Single channel

- Various systematics
  1. Effective mass of the pomeron.
  2. Different values for $N(s)$ scale parameters.
  3. Including $\rho\pi$ channel.

- $m(a_2) = 1307 \pm 1 \pm 6$ MeV
  $\Gamma(a_2) = 112 \pm 1 \pm 8$ MeV

- $m(a'_2) = 1720 \pm 10 \pm 60$ MeV
  $\Gamma(a'_2) = 280 \pm 10 \pm 70$ MeV
Table of Content

1 Introduction
   • Motivation
   • Data

2 Method

3 Coupled channel

4 Future prospects
Coupled channel

- $\eta^{(')}\pi$ coupled channel up to 2 GeV.
- $\rho\pi$ cannot be included without including big systematic contribution (Deck).
- We use a K-matrix approach with a Chew-Mandelstam phase space.

$$D^J(s)_{ki} = \left(K^J(s)^{-1}\right)_{ki} - \frac{s}{\pi} \int_{s_k}^{\infty} ds' \frac{\rho(s') N^J_{ki}(s')}{s'(s' - s - i\epsilon)},$$

$$\rho N^J_{ki}(s') = \delta_{ki} \frac{\lambda^{J+1/2} \left(s', m^2_{\eta^{(')}}, m^2_\pi\right)}{(s' + s_L)^{2J+1+\alpha}}$$

$$K^J_{ki}(s) = \sum_R g^J,R_k g^J,R_i \frac{m^2_R}{m^2_R - s} + c^J_{ki} + d^J_{ki} s.$$

- Just 1 K-matrix pole for the P-wave.
Coupled channel

- We use an average of 6 parameters for each figure.
- \( \chi^2 \approx 1.4 \), no significant deviation for any partial wave.
- 1 K-matrix pole produces 2 different peaks for the P-wave \( \rightarrow 300 \text{ MeV} \) distance.
Poles

- Statistical uncertainties calculated through bootstrapping
- \( m(a_2) = 1306.0 \pm 0.8 \pm 1.3 \) MeV \( \Gamma(a_2) = 114.4 \pm 1.6 \pm 0.0 \) MeV
- \( m(a_2') = 1722 \pm 15 \pm 67 \) MeV \( \Gamma(a_2') = 247 \pm 17 \pm 63 \) MeV
- Clearly compatible with the single channel case.
- All systematics (different LHC masses, numerator models ...) included.
Only one pole for the P-wave $\rightarrow m(\pi_1) = 1564 \pm 24 \pm 86$ MeV
$\Gamma(\pi_1) = 492 \pm 54 \pm 102$ MeV.
Table of Content

1 Introduction
   • Motivation
   • Data

2 Method

3 Coupled channel

4 Future prospects
Future

- New Gluex data?

- $2 \rightarrow 3$ FESR

- $\pi p \rightarrow \eta^{(s)} \pi p$ at COMPASS kinematics.
Summary

- Phenomenological analysis of COMPASS data → Analyticity and Unitarity.

- Past: JPAC and COMPASS collaboration to extract the ordinary $a_2(1320)$ and $a'_2(1700)$ resonances.

- This work: New method to analyze also the non-ordinary $\pi_1$. Just one resonance contrary to the PDG status.

- Future: Understanding Gluex exchanges.

- Future: Analytic dispersive constraints for $2 \rightarrow 3$. 
Thank you for your attention!