New determination of the lightest hybrid meson

Complutense University of Madrid, April 12, 2019

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Topical Gorup on Hadronic Physics

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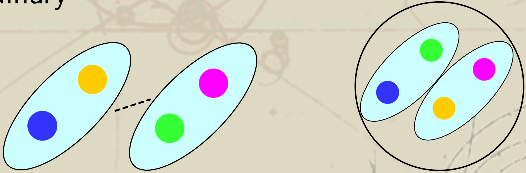
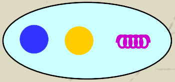
This work: Motivation

- In this talk: Recent analysis on spectroscopy
- Ordinary hadrons → first part of the talk

- Not so ordinary

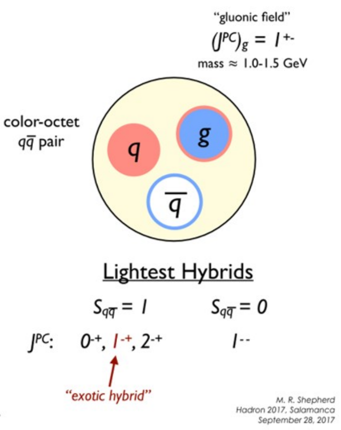


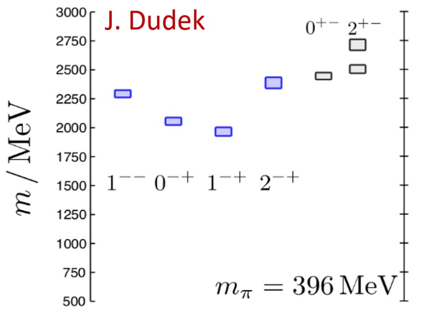
- Hybrid



This work: Motivation

- Only one hybrid expected.
- $J^{PC} = 1^{-+} \rightarrow$ lightest hybrid candidate.





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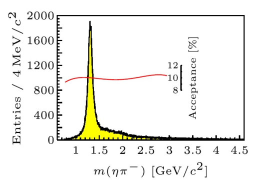
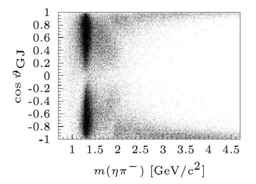
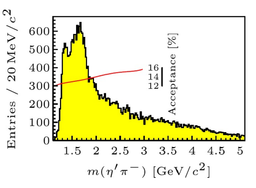
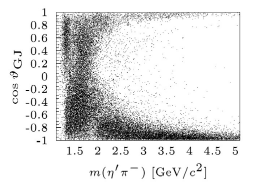
Data: COMPASS experiment

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





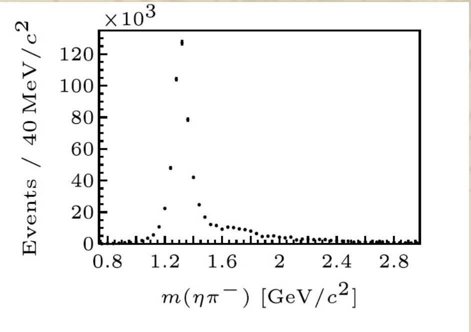


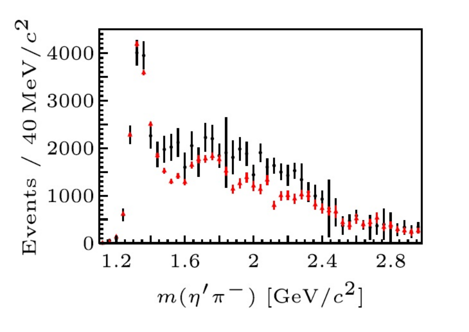


- Asymmetry$\rightarrow$ odd (exotic) waves.
- Dominated by $J^{PC} = 1^{-+} \Rightarrow$ non $q\bar{q}$ quantum numbers.

Status

- Clear $a_2(1320)$ decaying into $\eta\pi$ and $\eta'\pi$?





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

PDG status

$\pi_1(1400)$ $I^G(J^{PC}) = 1^-(1^{-+})$

$\pi_1(1400)$ MASS	1354 ± 25 MeV (S = 1.8)
$\pi_1(1400)$ WIDTH	330 ± 35 MeV

Decay Modes

	Mode	Fraction (Γ_i / Γ)
Γ_1	$\eta\pi^0$	seen
Γ_2	$\eta\pi^-$	seen
Γ_3	$\eta'\pi$	

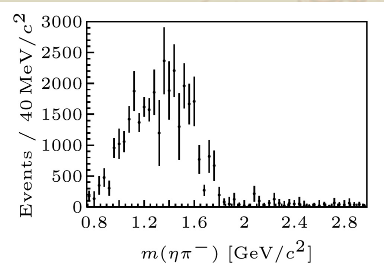
$\pi_1(1600)$ $I^G(J^{PC}) = 1^-(1^{-+})$

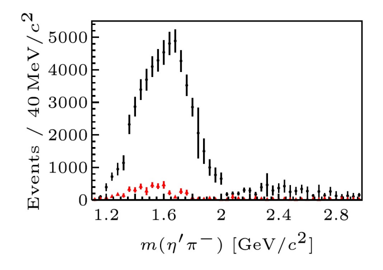
$\pi_1(1600)$ MASS	1662^{+8}_{-9} MeV
$\pi_1(1600)$ WIDTH	241 ± 40 MeV (S = 1.4)

Decay Modes

	Mode	Fraction (Γ_i / Γ)
Γ_1	$\pi\pi\pi$	seen
Γ_2	$\rho^0\pi^-$	seen
Γ_3	$f_2(1270)\pi^-$	not seen
Γ_4	$b_1(1235)\pi$	seen
Γ_5	$\eta'(958)\pi^-$	seen
Γ_6	$f_1(1285)\pi$	seen

- PDG reports 2 different resonances

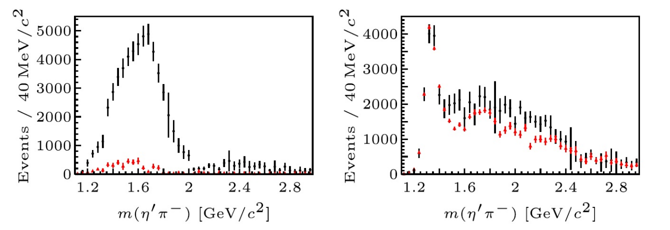




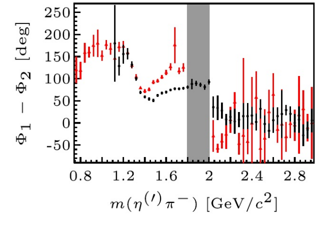
- $\pi_1(1400)$ decaying into $\eta\pi$? $\pi_1(1600)$ decaying into $\eta'\pi$?

Partial waves

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



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



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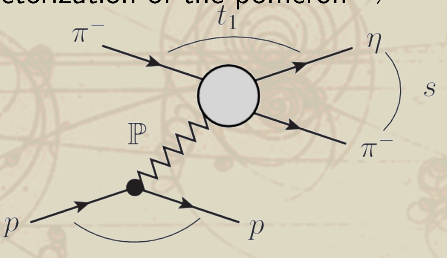
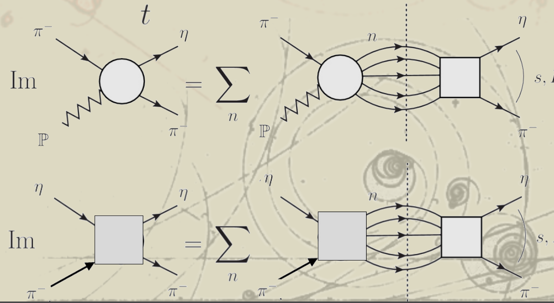
Method

- Based on AR et al. Phys.Rev.Lett. (2019), A.Jackura et al. Phys.Lett.B (2018)
- Peripheral production $\Rightarrow$ factorization of the pomeron $\Rightarrow$ $Ima(s) = \rho(s)t^*(s)a(s)$.

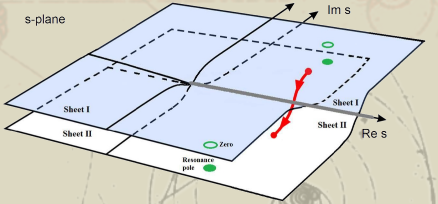


- Amplitude built around $t(s) = \frac{N(s)}{D(s)}$ method $\Rightarrow$ $a(s) = p^2 q \frac{n(s)}{D(s)}$.
- Smooth polynomials $n(s) = \sum_j a_j w^j(s)$



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 et al. (JPAC & COMPASS), PLB779, 464-472**

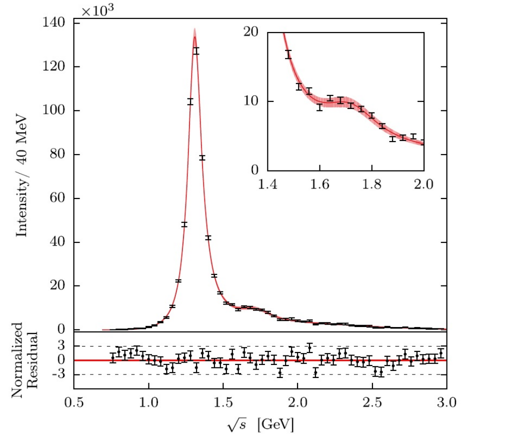
- $Imt(s) = \rho(s)|t(s)|^2 \Rightarrow ImD(s) = -\rho(s)N(s)$, so that

$$D(s) = D_0(s) - \frac{s}{\pi}\int_{s_{th}}^{\infty} ds' \frac{\rho(s')N(s')}{s'(s'-s)},$$

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

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

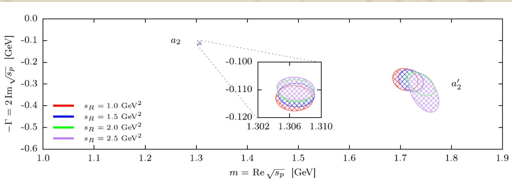
Single channel

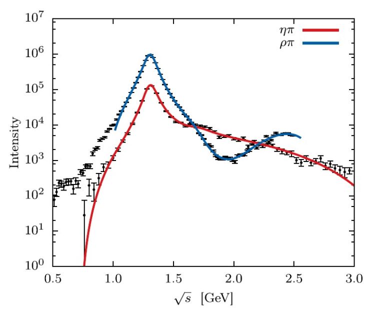


- 12 parameters, $\chi^2 \approx 2$.
- Good description of both peaks, the residuals of the fits follow a Gaussian distribution.

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 $\quad \Gamma(a_2) = 112 \pm 1 \pm 8$ MeV
- $m(a_2') = 1720 \pm 10 \pm 60$ MeV $\quad \Gamma(a_2') = 280 \pm 10 \pm 70$ MeV

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Coupled channel

- $\eta^{(\prime)}\pi$ 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.

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

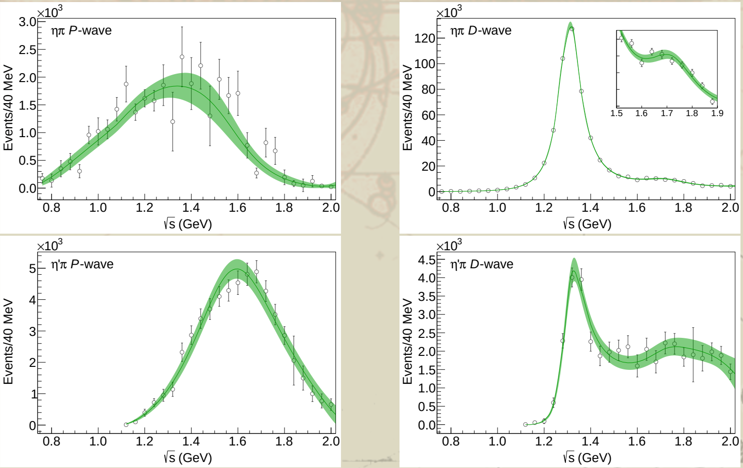
$$\rho N^J_{ki}(s') = \delta_{ki}\frac{\lambda^{J+1/2}\left(s', m^2_{\eta^{(\prime)}}, m^2_\pi\right)}{(s'+s_L)^{2J+1+\alpha}}$$

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

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

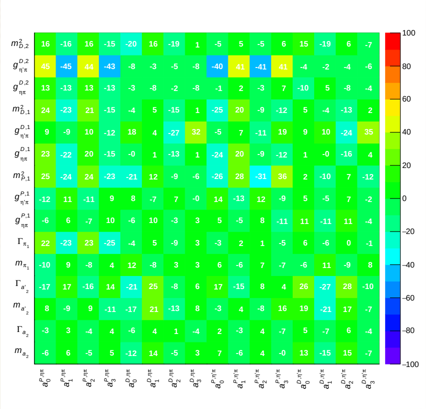
Coupled channel analysis

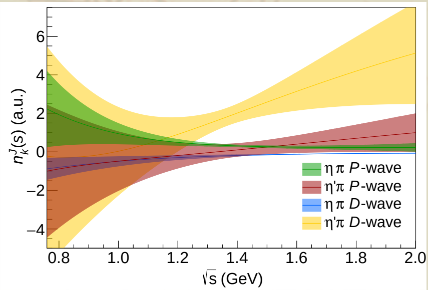
- Average of 6 parameters for each figure.
- $\chi^2 \approx 1.3$, no significant deviation for any partial wave.
- 1 K-matrix pole produces 2 different P-wave peaks.



Coupled channel analysis

- No correlation between $n^J(s)_k$ and $D^J(s)_{ki}$.

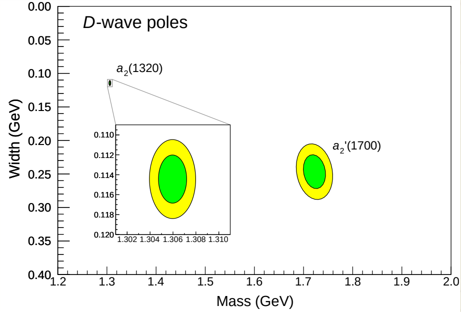


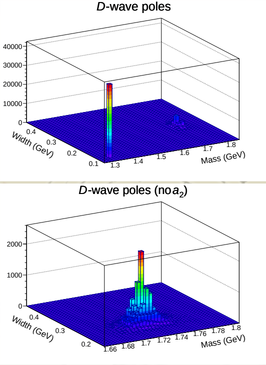


- Numerator is smooth and process dependant.

Poles

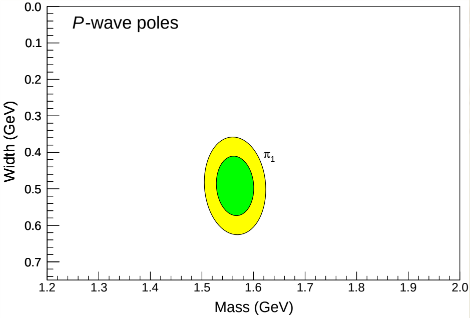
- Statistical uncertainties calculated through bootstraping
- $m(a_2) = 1306.0 \pm 0.8 \pm 1.3$ MeV $\Gamma(a_2) = 114.4 \pm 1.6 \pm 0.0$ MeV
- $m(a_2') = 1722 \pm 15 \pm 67$ MeV $\Gamma(a_2') = 247 \pm 17 \pm 63$ MeV
- All systematics (diferent LHC masses, numerator models ...) included.

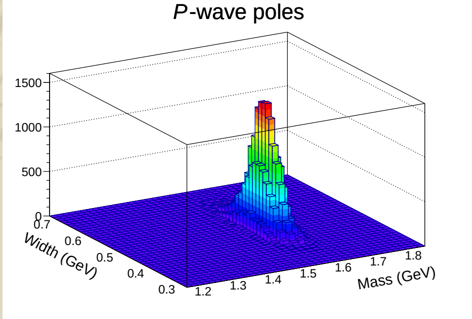




Poles

- Only one, isolated pole for the P-wave.
- $m(\pi_1) = 1564 \pm 24 \pm 86$ MeV $\qquad \Gamma(\pi_1) = 492 \pm 54 \pm 102$ MeV.





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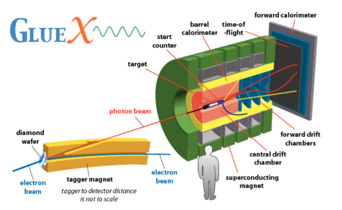
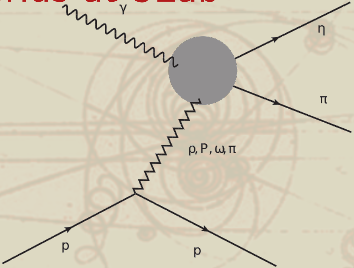
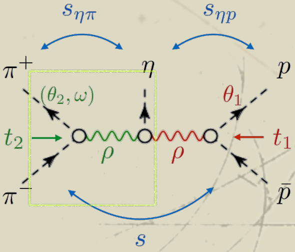
Future project: Hunting hybrids at JLab

- New GlueX/CLAS data?



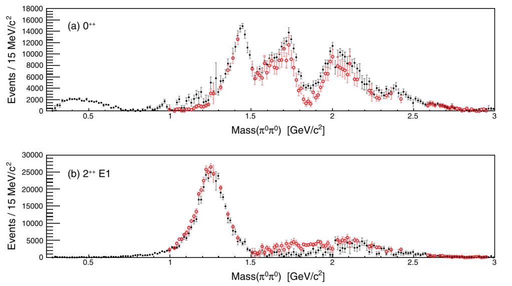


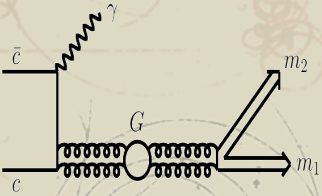
- $2 \to 3$ finite energy sum rules (FESR2)
- $\pi p \to \eta^{(\prime)} \pi p$ at JLAB kinematics.



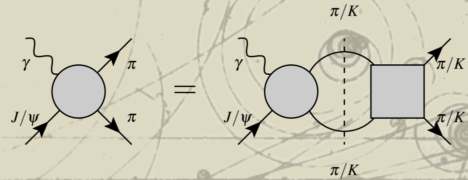
Future project: Hunting gluebalss with BESIII

- BESIII data on gluebal "rich" experiments.





- Slightly different kinematics



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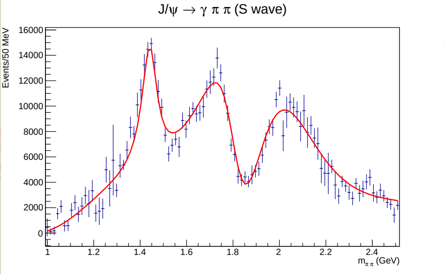

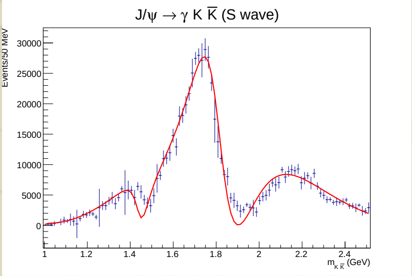

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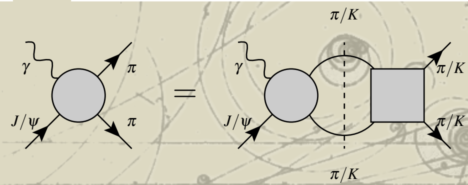

Summary

- Phenomenological analysis of COMPASS data $\rightarrow$ 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 π_1. Just one resonance opposed to the PDG.
- Future: Gluex
- Future: BESIII J/ψ radiative decays

Thank you for your attention!