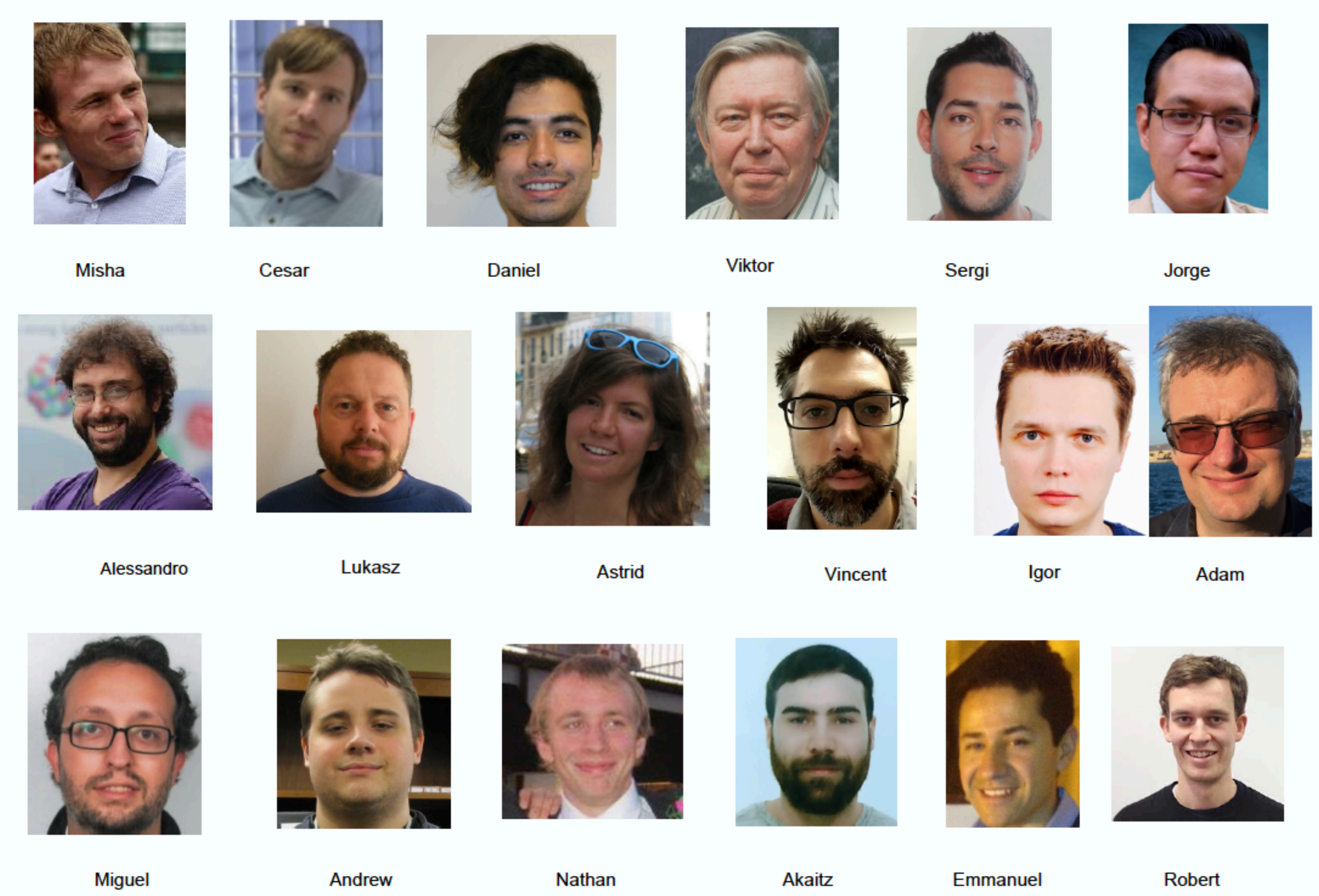
On the importance of understanding production (for spectroscopy)

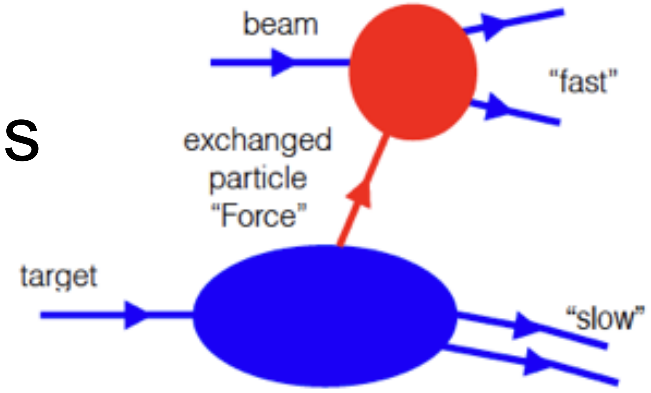
JPAC

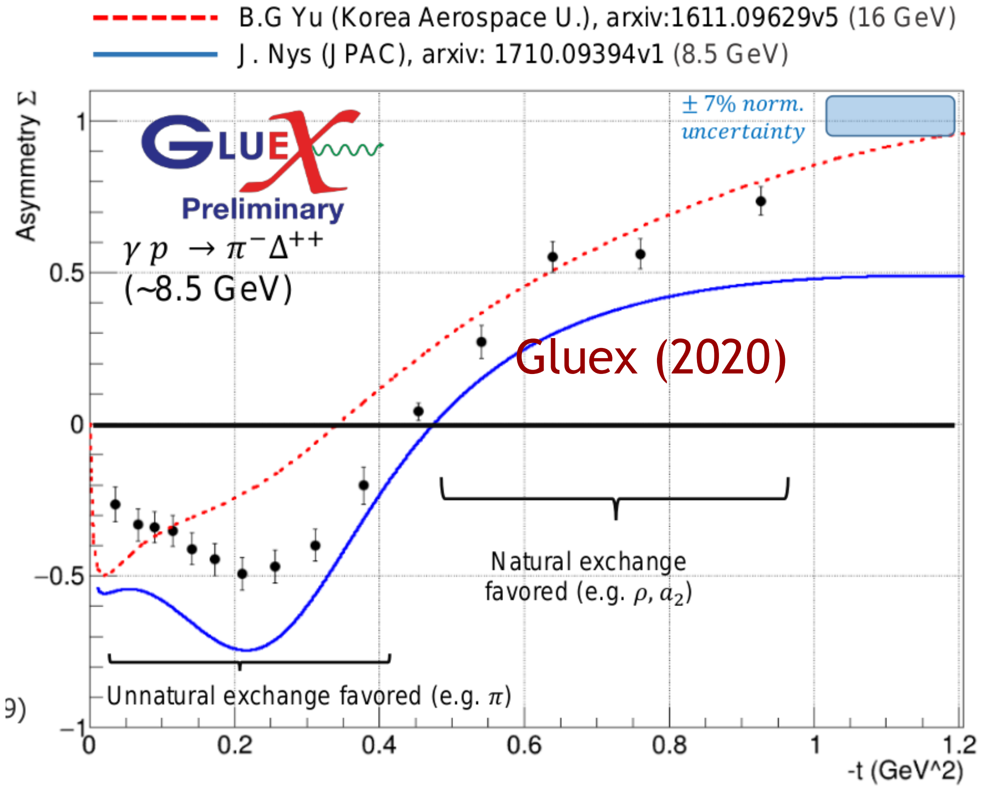
Adam Szczepaniak (KLF Collaboration Meeting, December 2020)



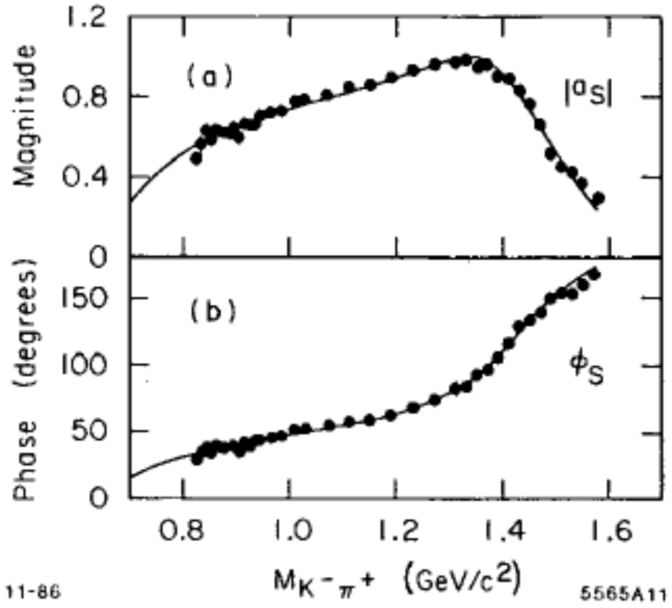
Importance of Regge Theory

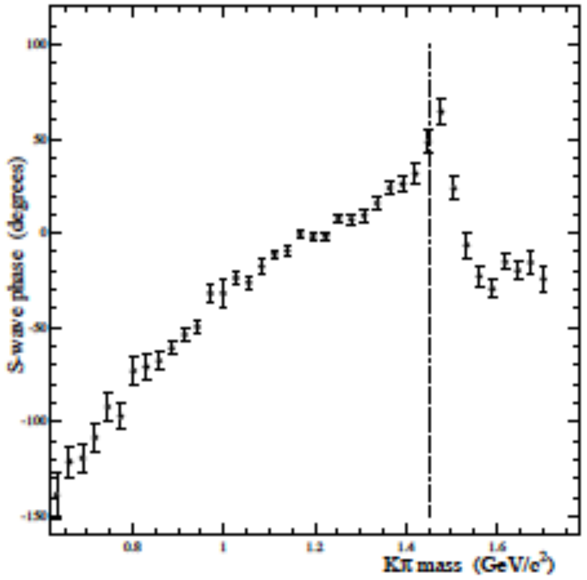
- To separate mesons from baryons one needs to establish (Regge) factorization





- Resonances are identified by phase motion : production/FSI phases can affect extraction of resonances

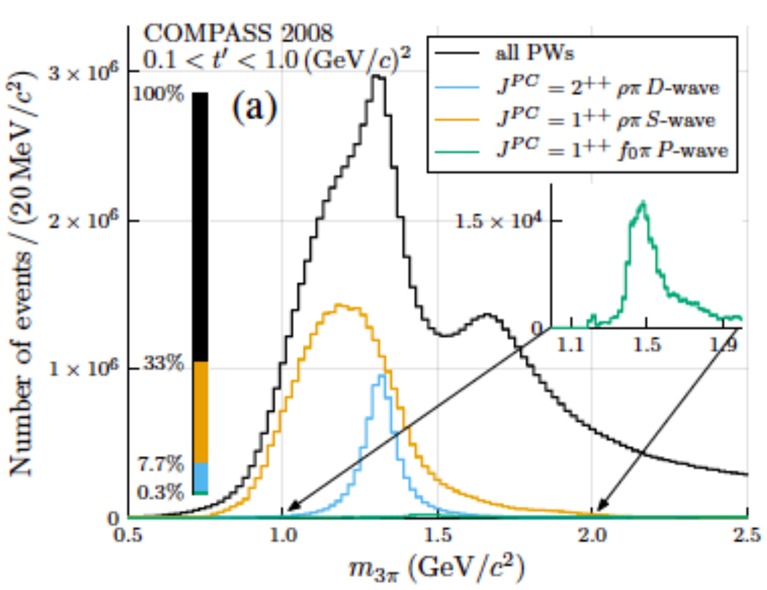


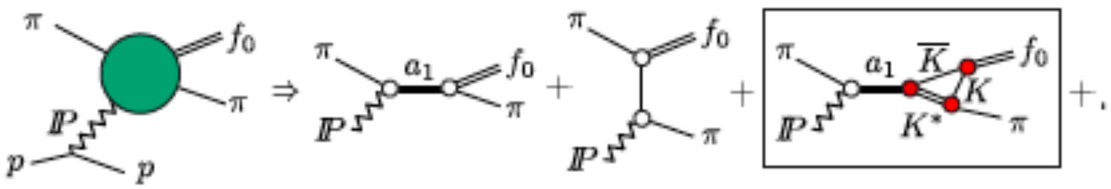


LASS $K^- p \to K^- \pi^+ n$

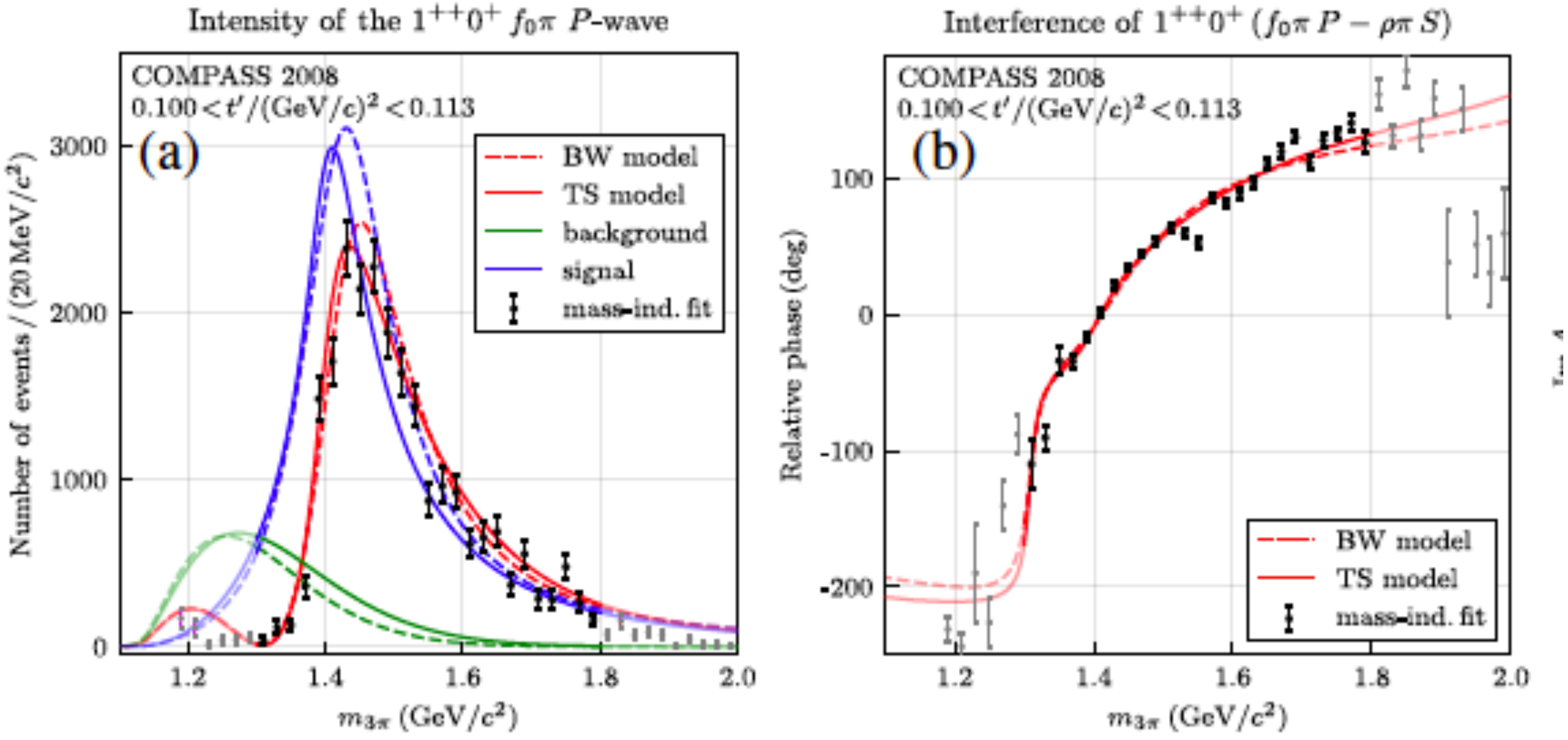
FOCUS $D^+ \to K^- \pi^+ \pi^-$

Not every bump is a resonance

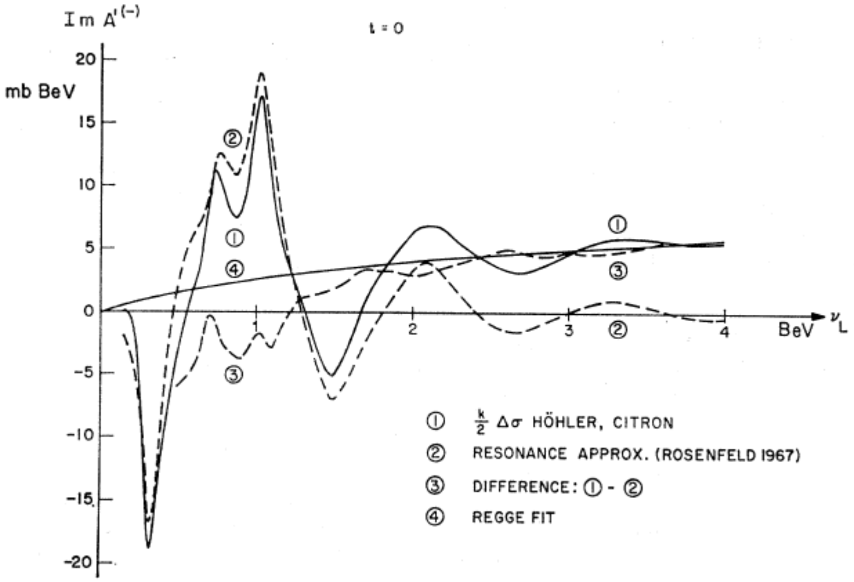




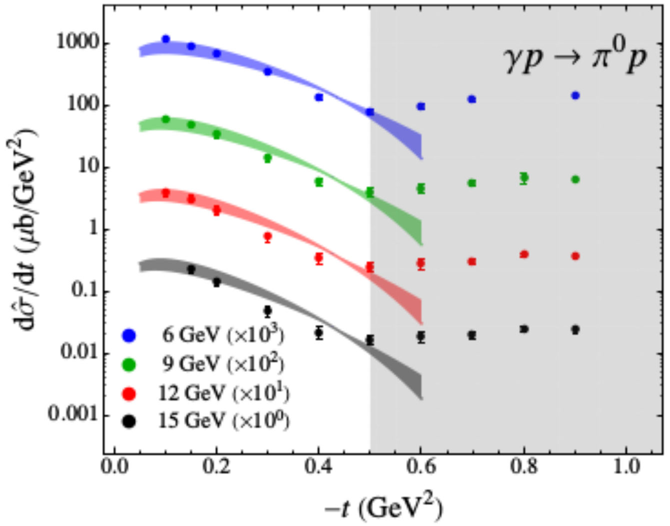
$a_1(1420)$ appears as a FSI effect on a tail for the $a_1(1260)$



reggeons are dual not additive



$$\int_0^{\Lambda} \mathrm{Im}\, A_i(\nu,t)\nu^k d\nu = \beta_i(t)\frac{\Lambda^{\alpha(t)+k}}{\alpha(t)+k}$$



Combine energy regimes

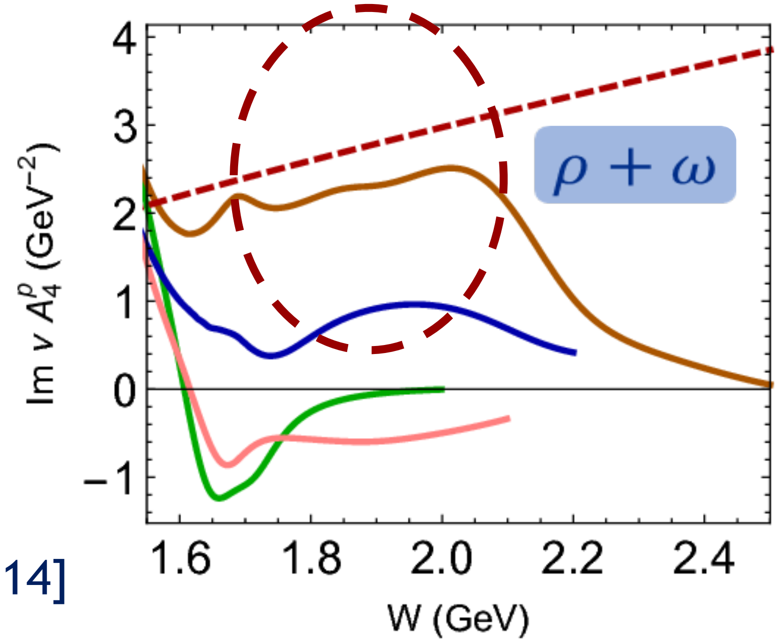
- Low-energy model ((SAID, MAID, Bonn-Gatchina, Julich-Bonn,…)
- Predict high-energy observables

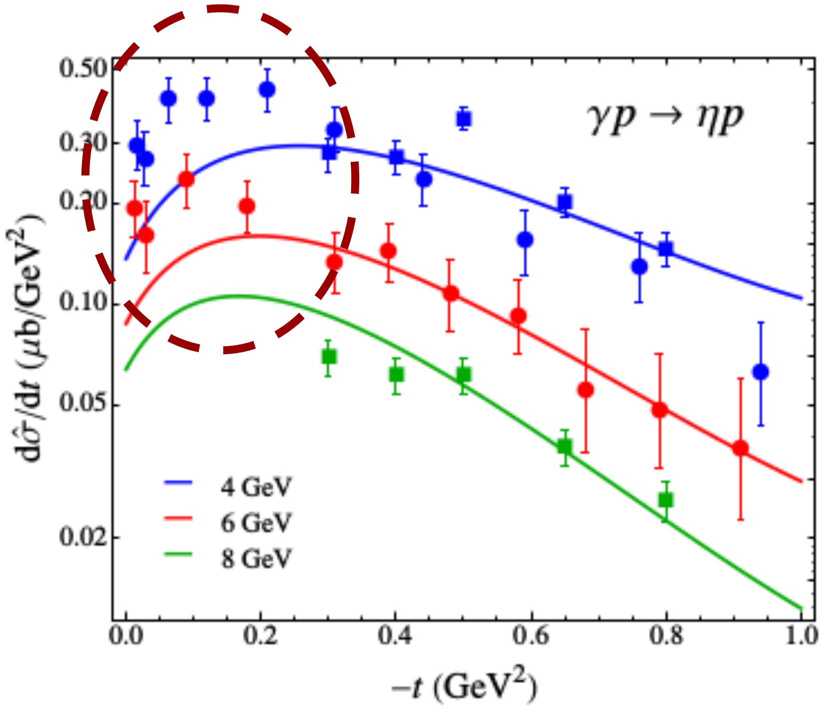
Ambiguities in the low-energy model (η-MAID)
→ Mismatch with high-energy data

Possibilities

- Low-energy model inconsistent
- Cut-off not high enough
  - High mass resonances!

[J.Nys *et al.*, (JPAC) PRD95 (2017) 034014]

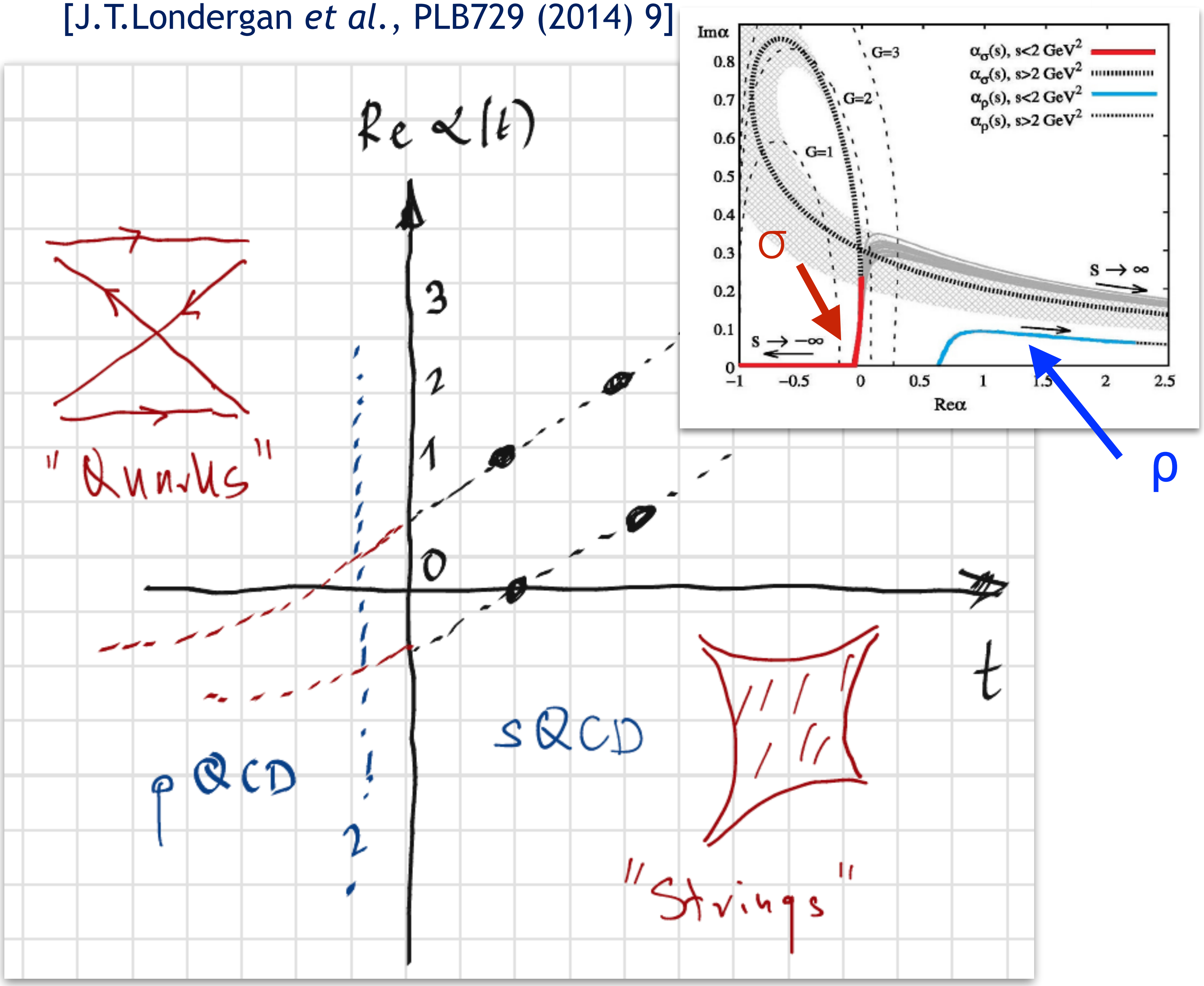




Importance of Regge Theory : Resonances

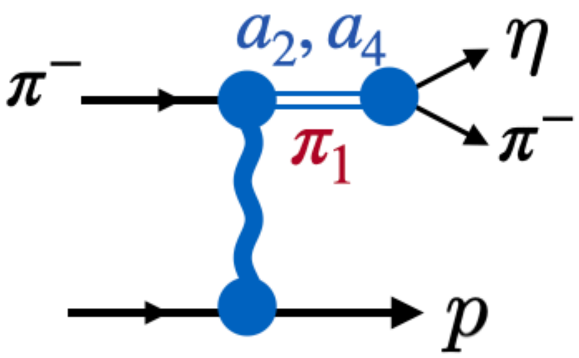
- Regge poles imply a relation between mass and spin which is a manifestation of the the microscopic dynamics

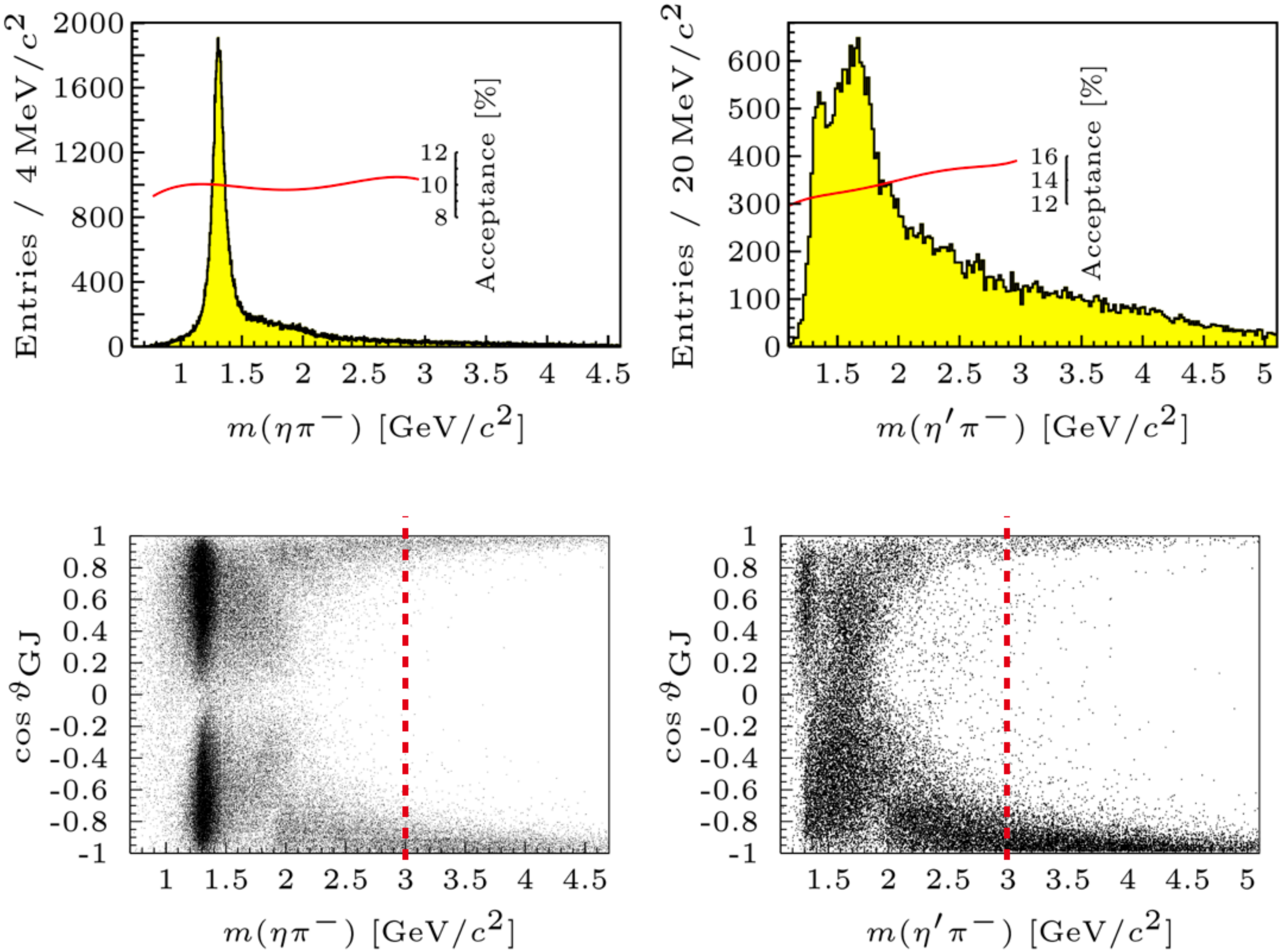
- Quark bound states (valence, tetra-quark, pentaquark) or hadron molecules have different pole trajectories



[J.T.Londergan *et al.*, PLB729 (2014) 9]

COMPASS : PLB740, 3030 (2015)





190 GeV beam,

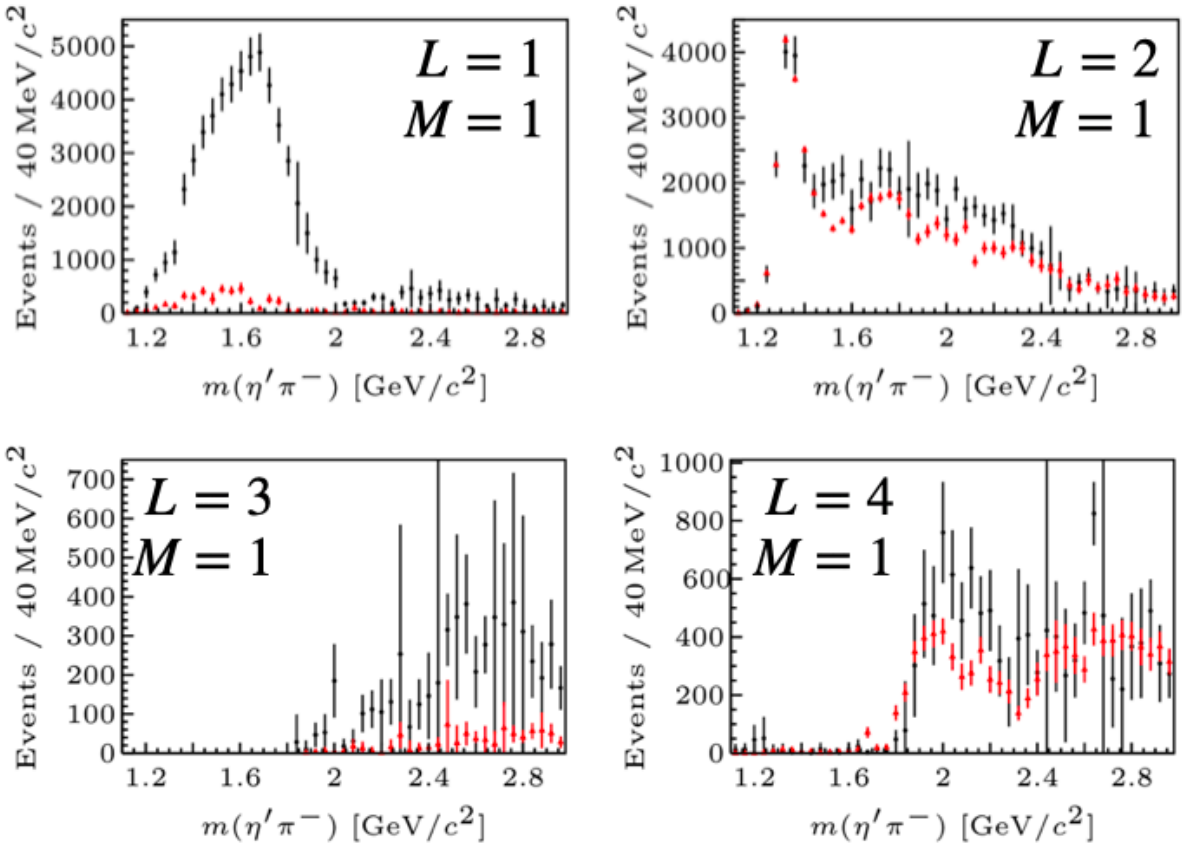
Only natural exchanges

No scalar, $M \geqslant 1$

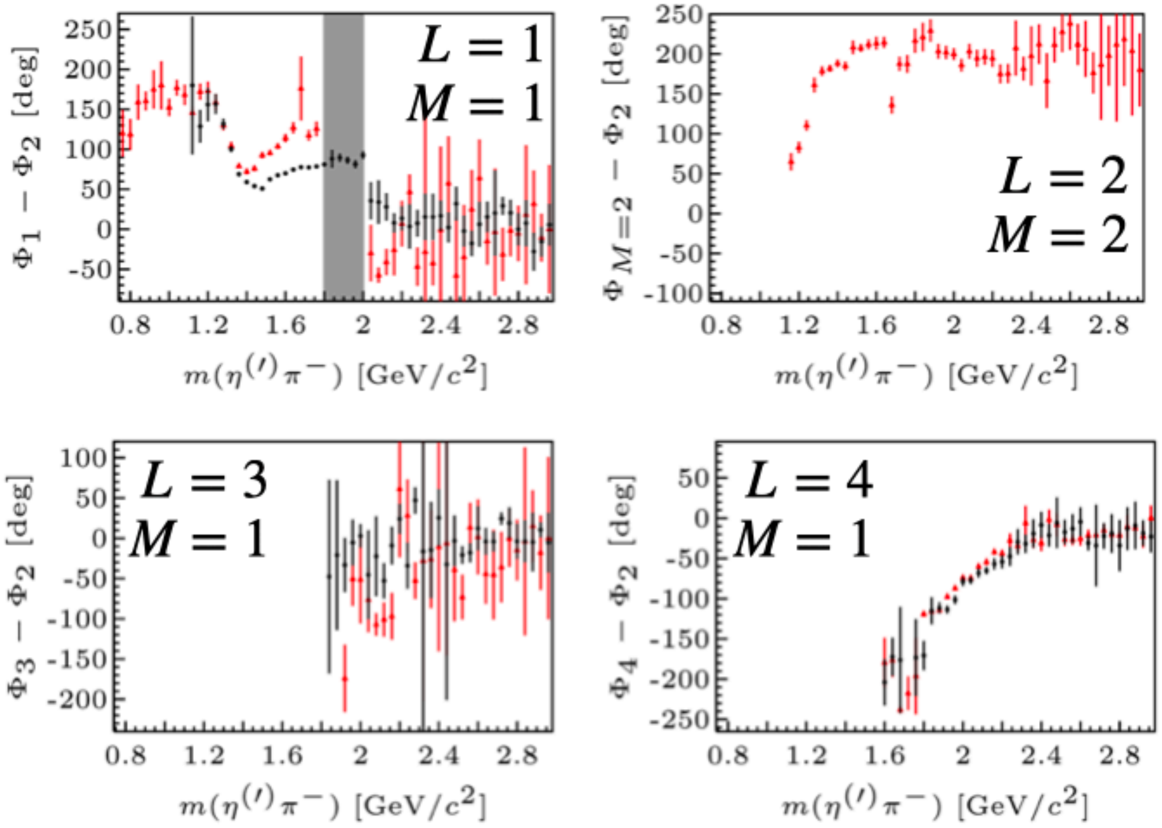
$A \propto \sin\theta \sin\phi$

Partial Waves up to L=6

Intensities



Phase difference w.r.t $L = 2$

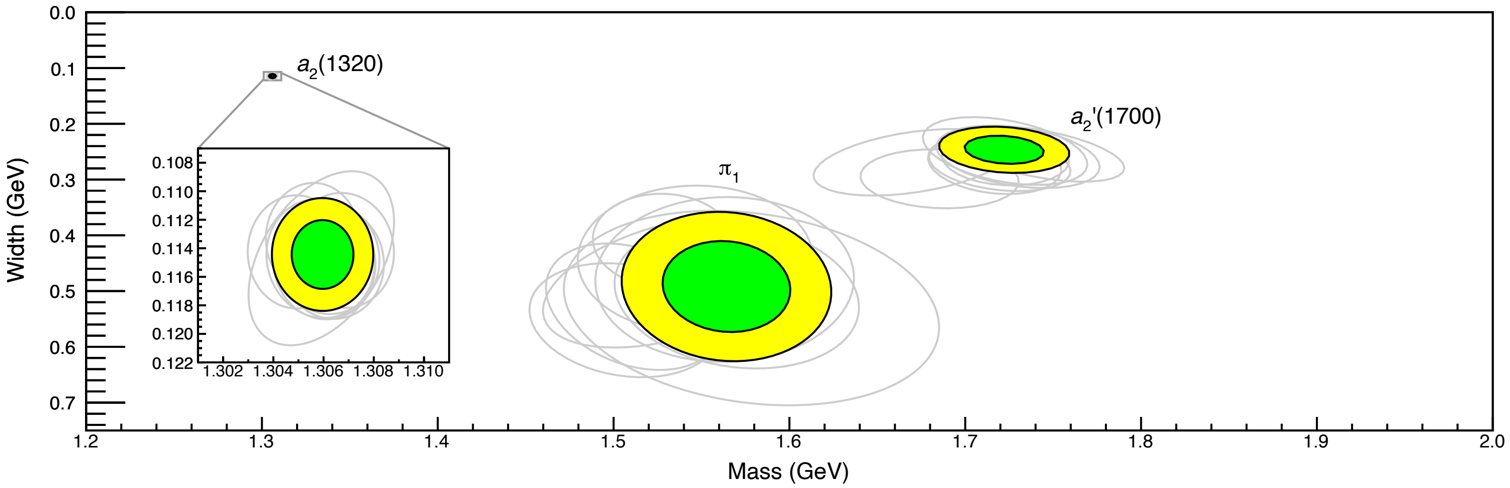


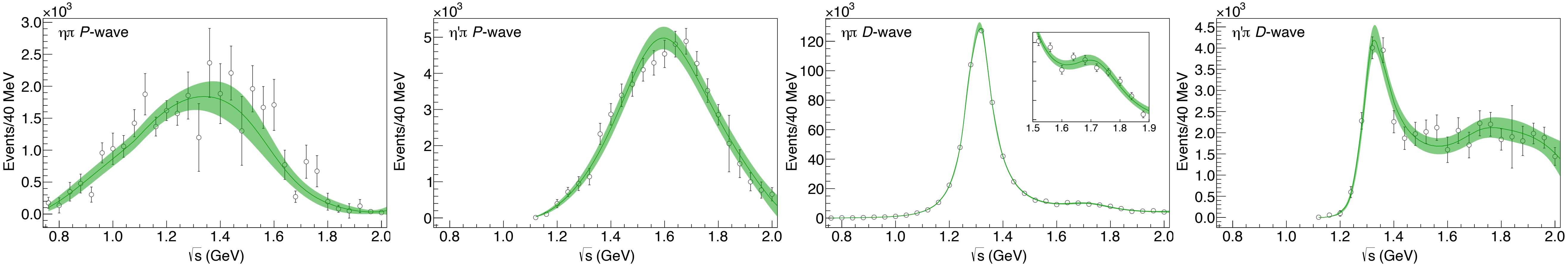
Hunting π_1 the hybrid

- Experiments (E852,CB,VES) announce **two** states, separately coupling to $\eta\pi$ and $\eta'\pi$: difficult to reconcile with lattice and phenomenology

- Analyticity, unitarity: coupled-channel analysis of P,D waves in $\pi p \to \eta^{(\prime)}\pi p$.

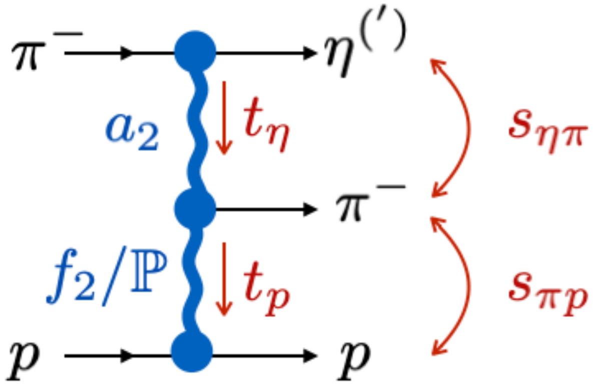
- Need for a **single** pole in P wave: π_1 (two poles show no improvement), two poles in D wave: a_2 and a_2'.

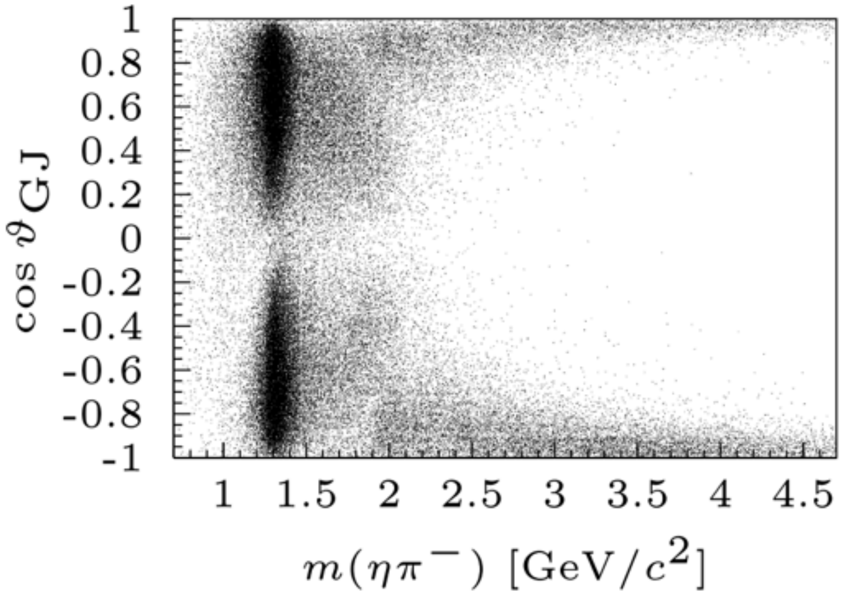


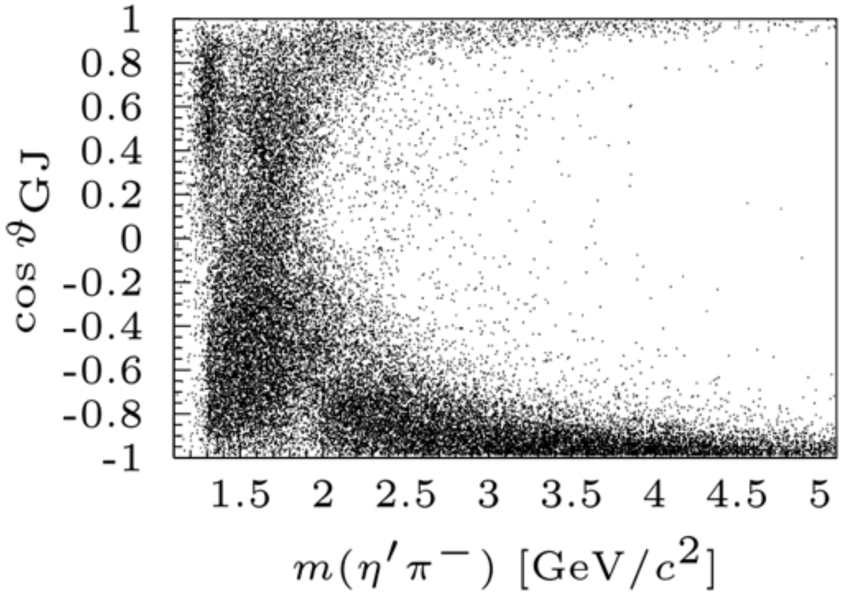


[A.Rodas, et al JPAC, PRL122 (2019) 042002] [Data : COMPASS, PLB740 (2015) 303]

High Energy Model : JPAC in preparation





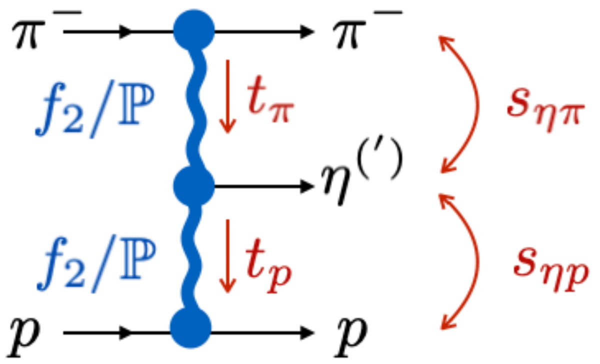


$$\alpha_{a_2}(t) = 0.47 + 0.9t$$

$$\alpha_{f_2}(t) = 0.47 + 0.89t$$

$$\alpha_{\mathbb{P}}(t) = 1.08 + 0.25t$$

Total of 6 amplitudes

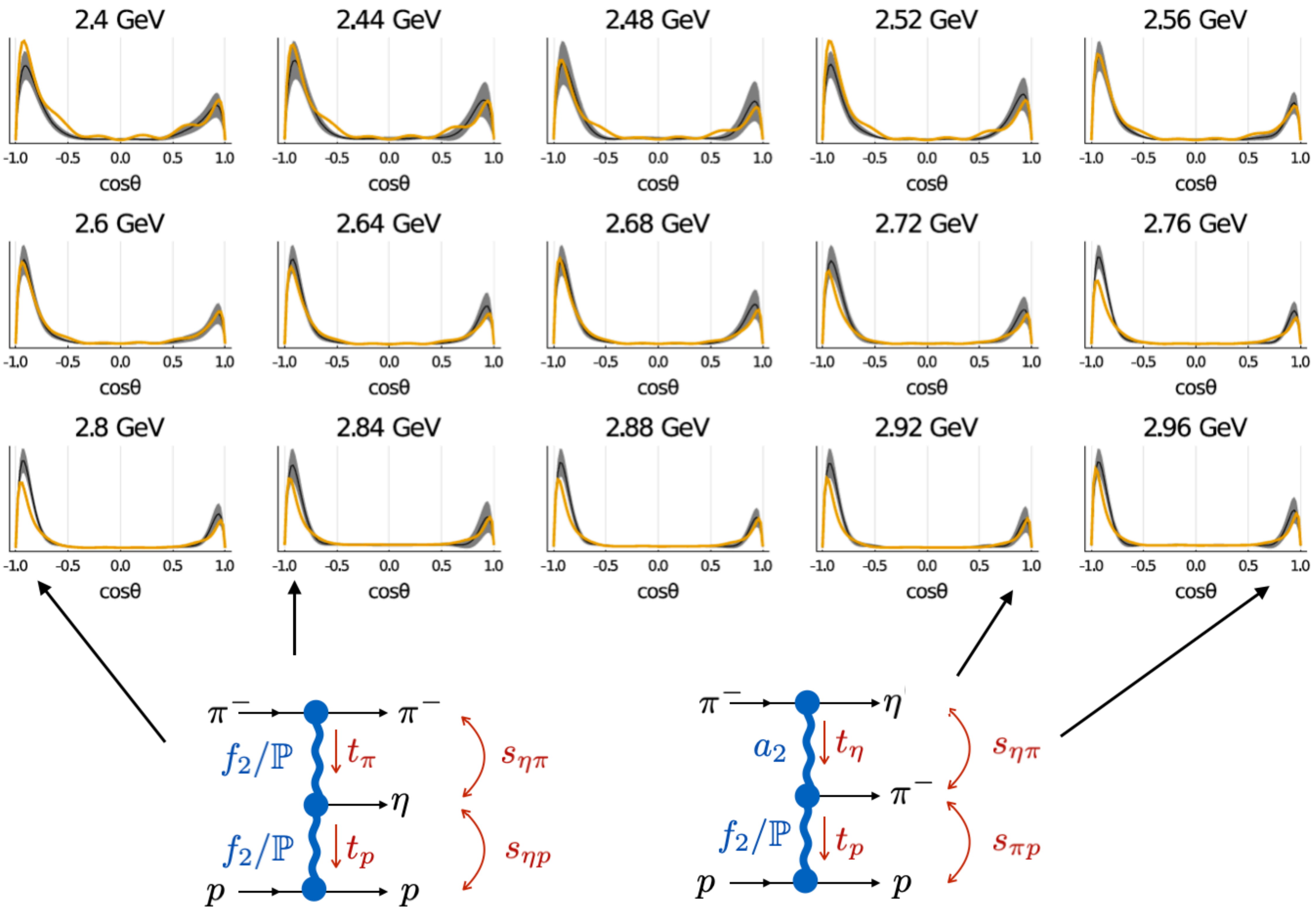


$$T^{\tau_1\tau_2}_{\alpha_1,\alpha_2}(s_1,s_2) = -K\Gamma(1-\alpha_1)\Gamma(1-\alpha_2)(\alpha' s)^{-1}(\alpha' s_1)^{\alpha_1}(\alpha' s_2)^{\alpha_2} \times \left[\eta^{\alpha_1}\xi_1\xi_{21}V(\alpha_1,\alpha_2,\eta) + \eta^{\alpha_2}\xi_2\xi_{12}V(\alpha_2,\alpha_1,\eta)\right]$$

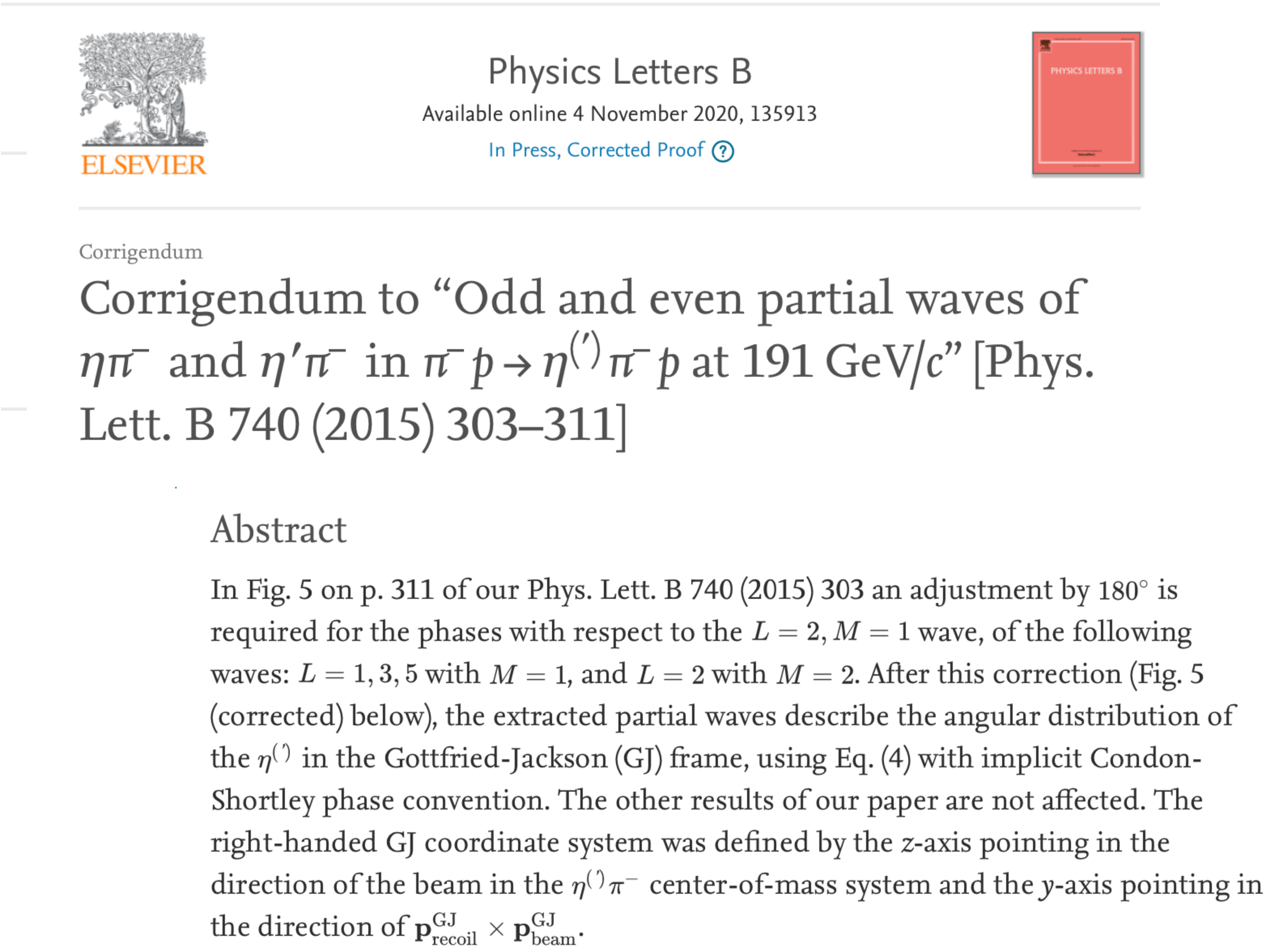
$$V(x,y,\eta) = \frac{\Gamma(x-y)}{\Gamma(1-y)}\,{}_1F_1(1-x, 1-x+y, -1/\eta)$$

$$K = 4m_{\eta\pi}p_a p_\eta p_b \sin\chi\sin\theta\sin\phi$$

Fit results


2.4 GeV
2.44 GeV
2.48 GeV
2.52 GeV
2.56 GeV
2.6 GeV
2.64 GeV
2.68 GeV
2.72 GeV
2.76 GeV
2.8 GeV
2.84 GeV
2.88 GeV
2.92 GeV
2.96 GeV
-1.0
-0.5
0.0
0.5
1.0
cosθ
π^-
π^-
$f_2/\mathbb{P}$
t_π
$s_{\eta\pi}$
η
$f_2/\mathbb{P}$
t_p
$s_{\eta p}$
p
p
π^-
η
a_2
t_η
$s_{\eta\pi}$
π^-
$f_2/\mathbb{P}$
t_p
$s_{\pi p}$
p
p

Theory is important



ELSEVIER

Physics Letters B

Available online 4 November 2020, 135913

In Press, Corrected Proof ?

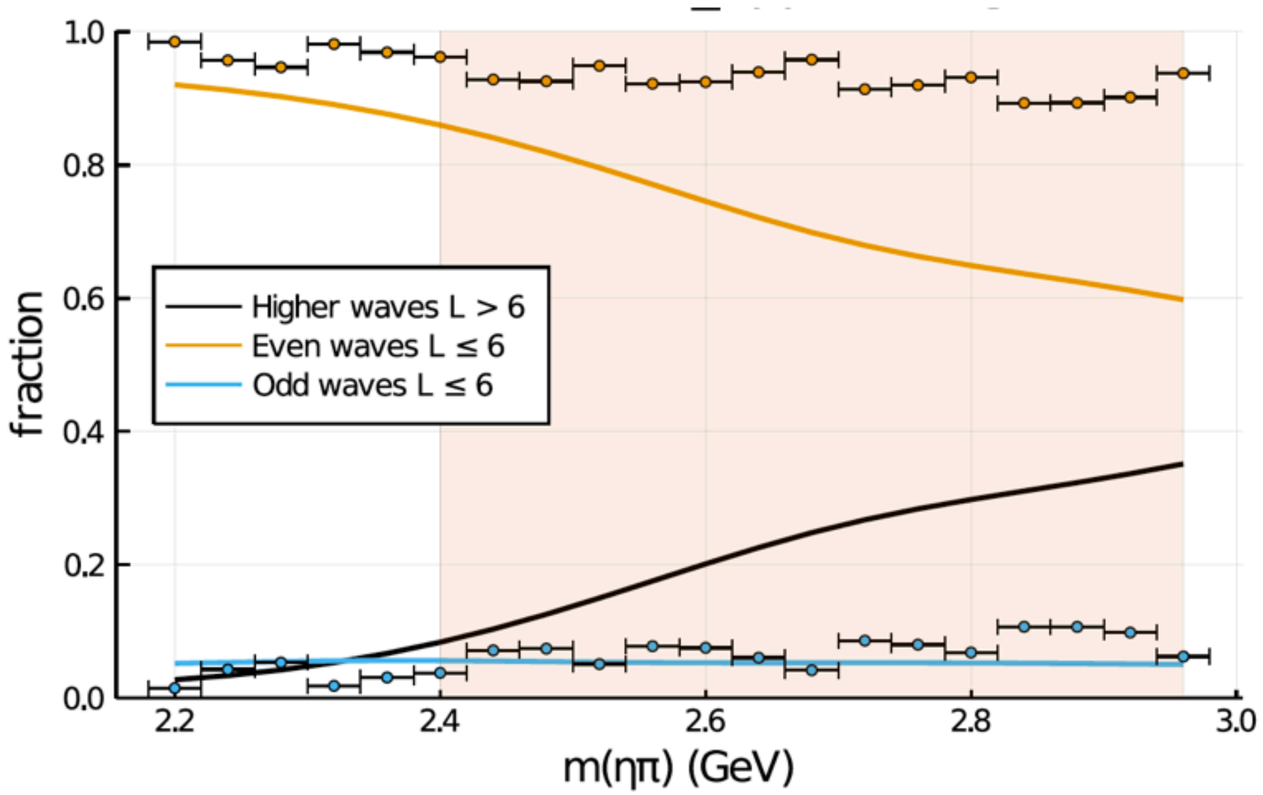
Corrigendum

Corrigendum to “Odd and even partial waves of $\eta\pi^-$ and $\eta'\pi^-$ in $\pi^- p \to \eta^{(\prime)}\pi^- p$ at 191 GeV/c” [Phys. Lett. B 740 (2015) 303–311]

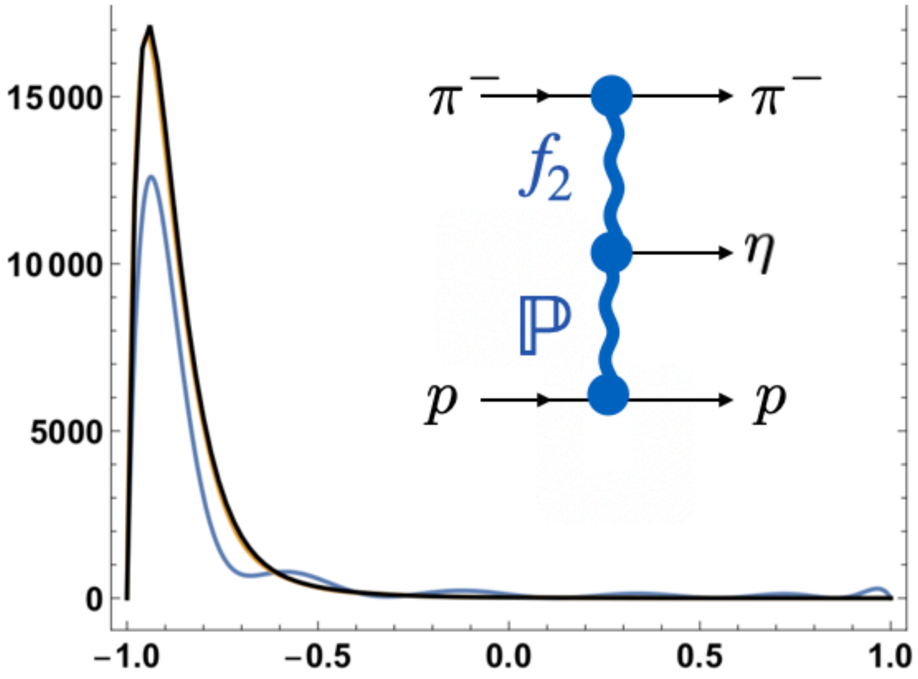
Abstract

In Fig. 5 on p. 311 of our Phys. Lett. B 740 (2015) 303 an adjustment by 180° is required for the phases with respect to the $L = 2, M = 1$ wave, of the following waves: $L = 1, 3, 5$ with $M = 1$, and $L = 2$ with $M = 2$. After this correction (Fig. 5 (corrected) below), the extracted partial waves describe the angular distribution of the $\eta^{(\prime)}$ in the Gottfried-Jackson (GJ) frame, using Eq. (4) with implicit Condon-Shortley phase convention. The other results of our paper are not affected. The right-handed GJ coordinate system was defined by the z-axis pointing in the direction of the beam in the $\eta^{(\prime)}\pi^-$ center-of-mass system and the y-axis pointing in the direction of $\mathbf{p}^{\mathrm{GJ}}_{\mathrm{recoil}} \times \mathbf{p}^{\mathrm{GJ}}_{\mathrm{beam}}$.

PWA vs Amplitude fits



- Compass fits with $L \leq 6$ PW's
- Model has infinite number of waves
- $L \leq 6$ waves give only ~80% of the data
- Careful with interpretation of the PW's for a truncated fit



Black = full diagram

Blue = up to $L = 6$

Orange = up to $L = 10$

Summary

- Need to establish factorization to isolate resonance production.

- Resonances are dual to cross-channel exchanges (reggeons)

— this is useful when constraining resonance parameters e.g via FESR's

— can shed light onto the resonance's nature, e.g large N_c arguments