Systematic Study of the Leakage Peak in the Partial-Wave Decomposition of the $\eta\pi$ Final State at COMPASS

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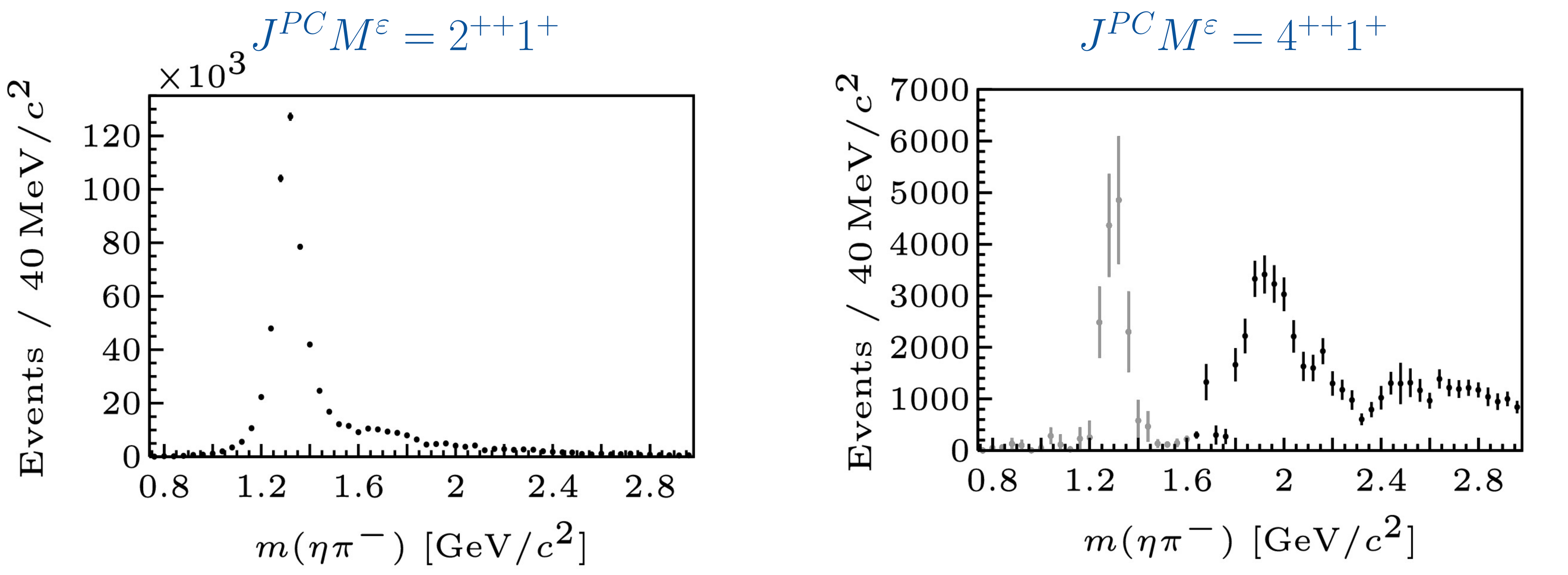
Motivation

In the partial-wave decomposition (PWD) results of the $\eta\pi$ final state, an unphysical peak at around $1.3\,\mathrm{GeV}/c^2$ in the $J^{PC}M^\varepsilon = 4^{++}1^+$ G-wave is observed. What is the origin of this structure?



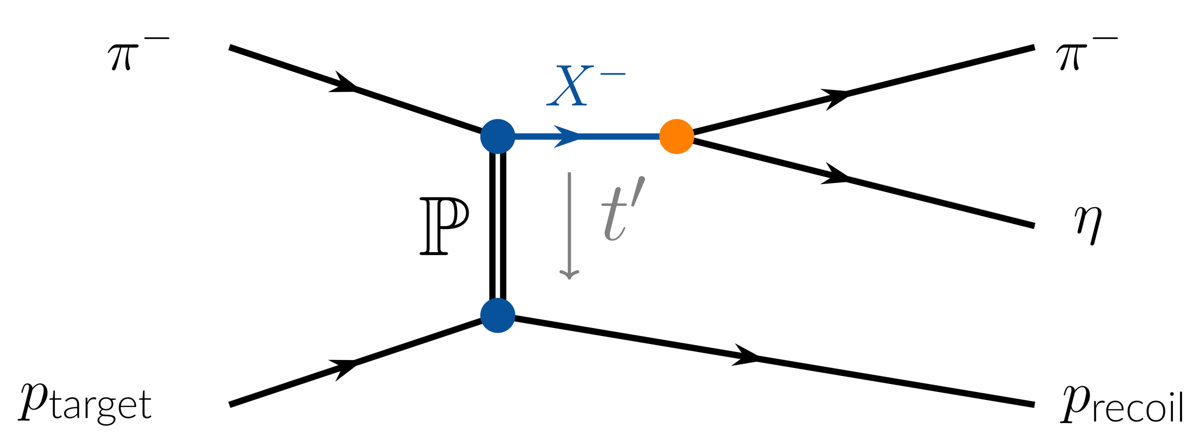
[1] C. Adolph et al., Odd and even partial waves of $\eta\pi^-$ and $\eta'\pi$ in $\pi^- p \to \eta^{(\prime)}\pi^- p$ at 191 GeV/c, Physics Letters B, Volume 740, 2015

Idea:

- Generate pseudo data using fully controlled input model
- Perform PWD of produced pseudo data
- Systematically investigate the origin of the leakage peak

PWD of the $\eta\pi$ Final State

Diffractive production of the $\eta\pi$ final state



Partial-Wave Decomposition

- The data is split into (m_X, t')-bins
- Intensity of each event k is decomposed in sum over partial-wave amplitudes of waves a:

$$\mathcal{I}(\tau_k) = \sum_{\varepsilon=\pm1} \left| \sum_{a}^{N^\varepsilon_\mathrm{waves}} \mathcal{T}^\varepsilon_a \Psi^\varepsilon_a(\tau_k) \right|^2 = \sum_{\varepsilon=\pm1} \sum_{a,b} \Psi^\varepsilon_a(\tau_k)\varrho^\varepsilon_{ab}\Psi^{\varepsilon *}_a(\tau_k)$$

- $\mathcal{T}^\varepsilon_a$ describes production and propagation of resonance X^-
- $\Psi^\varepsilon_a := \bar{\Psi}^\varepsilon_a/\sqrt{I^\varepsilon_{aa}}$ describes the decay within the isobar-model

Extended Likelihood Fit

- Data is fitted, performing an extended maximum likelihood fit in each kinematic cell:

$$\ln \mathcal{L}_\mathrm{ext} = \sum_{k=1}^{N_\mathrm{data}} \ln \left[\sum_{\varepsilon=\pm1} \left| \sum_{a}^{N^\varepsilon_\mathrm{waves}} \mathcal{T}^\varepsilon_a \Psi^\varepsilon_a(\tau_k) \right|^2 \right] - \sum_{\varepsilon=\pm1} \sum_{a,b}^{N^\varepsilon_\mathrm{waves}} \mathcal{T}^\varepsilon_a \mathcal{T}^{\varepsilon *}_b I^{\varepsilon,\mathrm{acc}}_{ab}$$

Pseudo Data Generation

Pseudo Data Generation

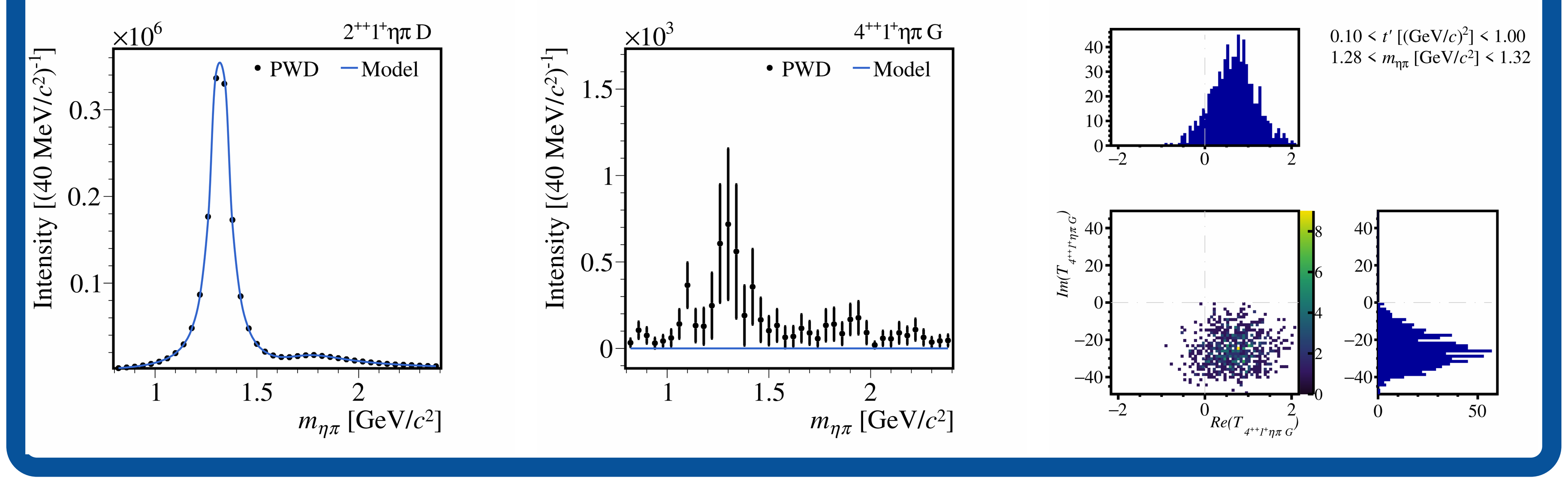
1. Generate flat phase-space data: $\pi^- + p \to \eta\pi + p$
2. Calculate intensity for each event according to toy model
3. Draw pseudo data using rejection sampling

Toy-Model:

$$\mathcal{T}_a(m_X, t') = \sqrt{m_X}\, \underbrace{\mathcal{P}(m_X, t')}_{\text{Production}} \left[\sum_{R\in\mathbb{S}_a} \underbrace{C^R_a}_{\text{Coupling}} \cdot \underbrace{D^\mathrm{BW}_R(m_X; M_R, \Gamma_R)}_{\substack{\text{Dynamical Amplitude} \\ \text{(rel. Breit-Wigner)}}} \right]$$

Minimal Input Model

- Generate D-wave including dominant $a_2(1320)$ and weak $a_2'(1700)$
- Exclude t'-dependence and any acceptence effects
- Perform PWD including D- and G-wave $\to$ monitor leakage
- Quantify effect by using bootstrap method: $\approx 0.3\%$ leakage

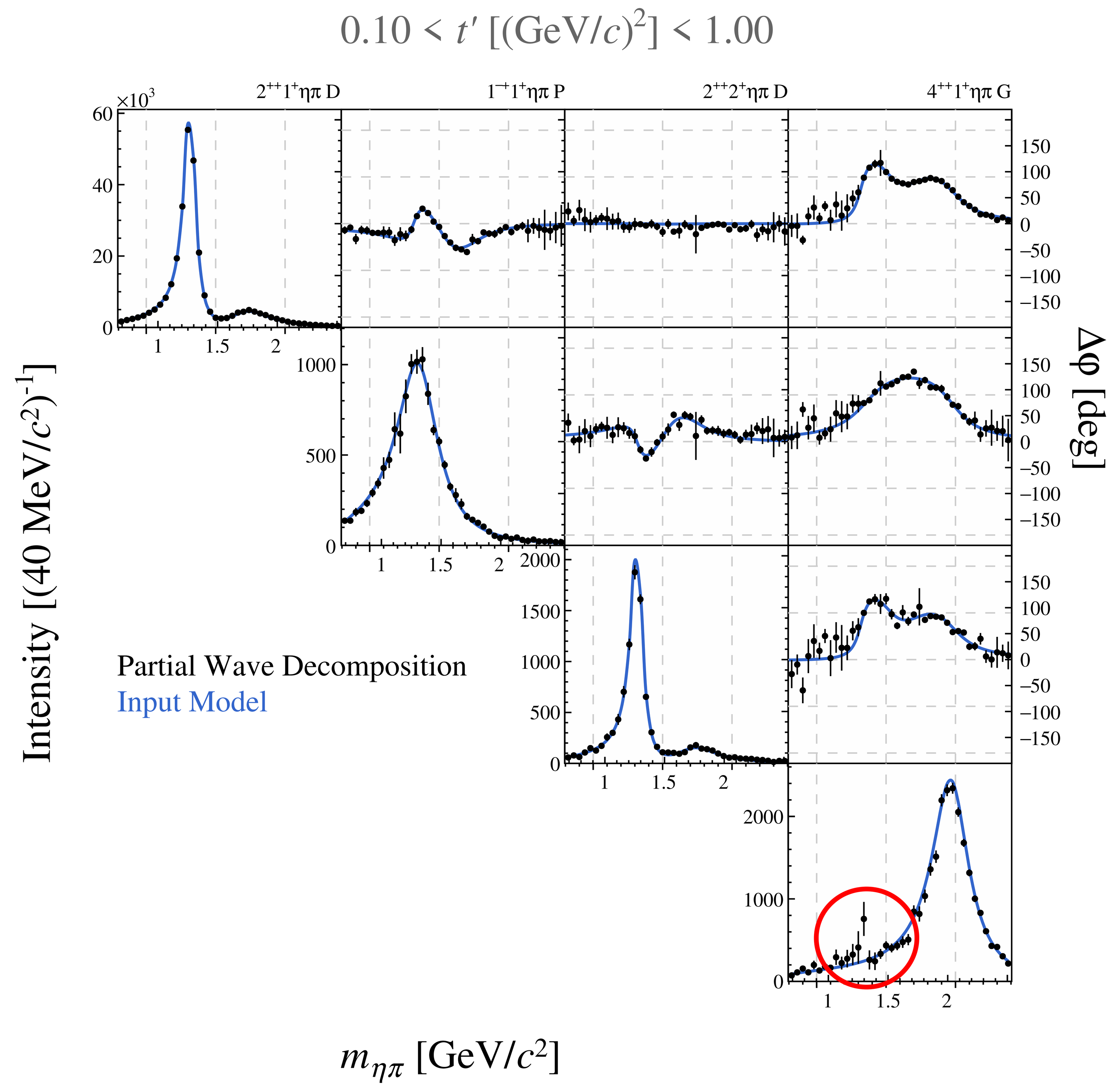


PWD of Realistic Input Model

Adding Model Complexity

In order to reflect the behavior of a more realistic data set, we add some complexity to the model:

- Include π_1 and $a_4(1940)$ states and additional partial-waves
- Add t'-dependence through $\mathcal{P}(m_X, t')$
- Incorporate acceptance description of the detector



Even with full control over the input model, the leakage peak is still visible in the PWD results. Due to the feed through of the dominant $a_2(1320)$, the leakage amounts up to $\approx 1.5\%$ which is in the same order as stated for real data in [1] (3%).

Conclusion

- Model cannot unambiguously distinguish between $J^{PC}M^\varepsilon = 2^{++}1^+$ D- and $J^{PC}M^\varepsilon = 4^{++}1^+$ G-wave
- Due to dominant $a_2(1320)$ this effect becomes visible, for smaller coupling the effect is negligible
- The leakage peak becomes more pronounced by increasing model complexity: t'-dependence, acceptance correction …
- We can rule out numerical inaccuracies of the integral matrices or an insufficient acceptance description as the origin of the leakage peak structure

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