Future Directions in Spectroscopy Analysis

DOUBLE-REGGE CONTRIBUTION TO $\eta^{(\prime)}\pi$ PRODUCTION

Sunset in Madrid

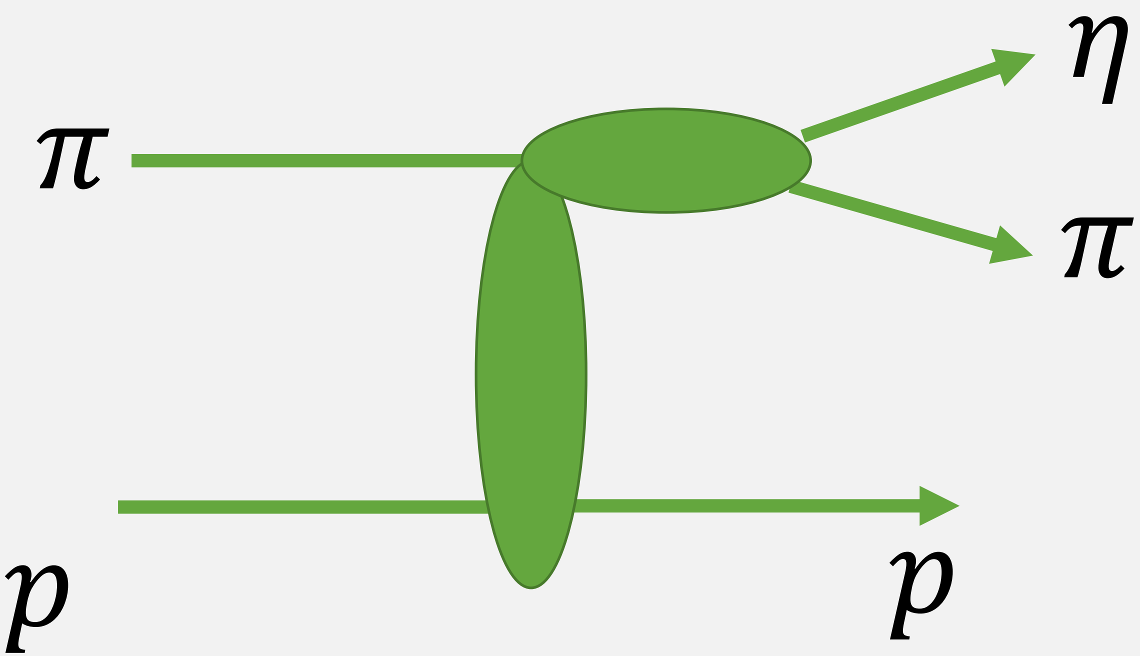
César Fernández Ramírez

#SOMOS2030 GOBIERNO DE ESPAÑA MINISTERIO DE EDUCACIÓN Y FORMACIÓN PROFESIONAL CONACYT dgapa PAPIIT - PAPIME

JPAC Instituto de Ciencias Nucleares UNAM UNED

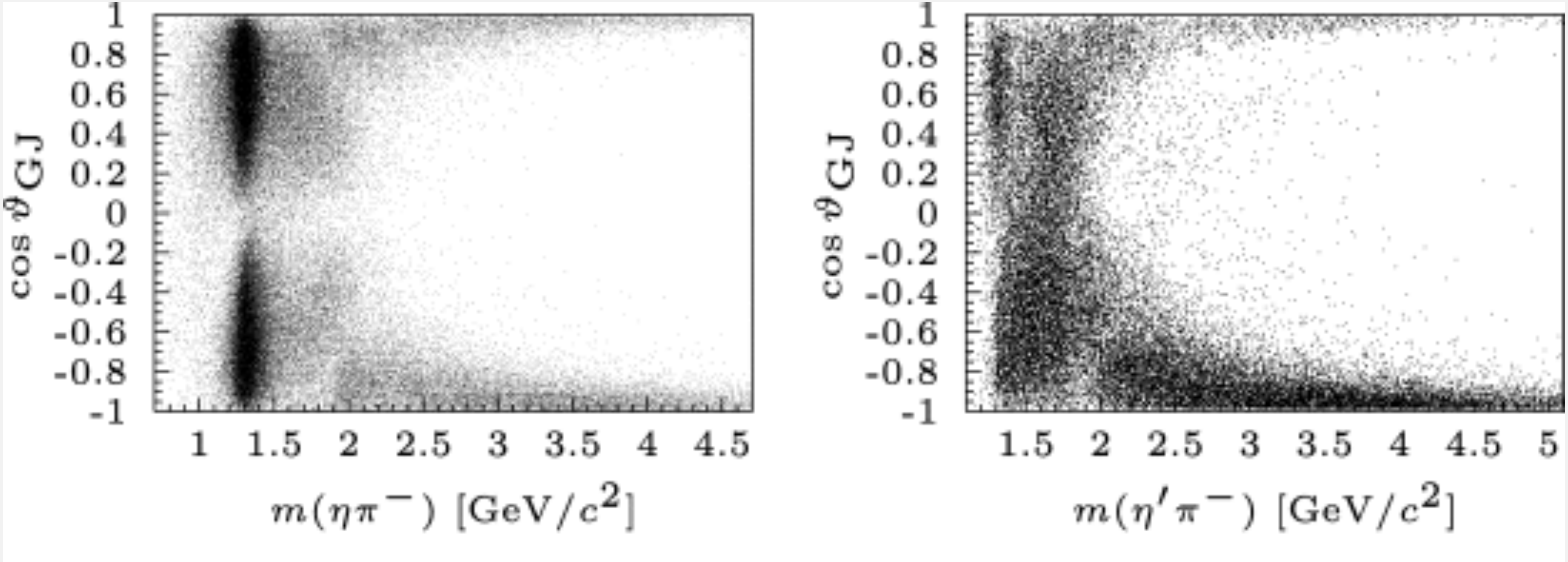
Pion diffractive dissociation

$$\pi^-(q) + p(p_1) \to \eta^{(\prime)}(k_\eta) + \pi^-(k_\pi) + p(p_2)$$



Check out Boris' talk

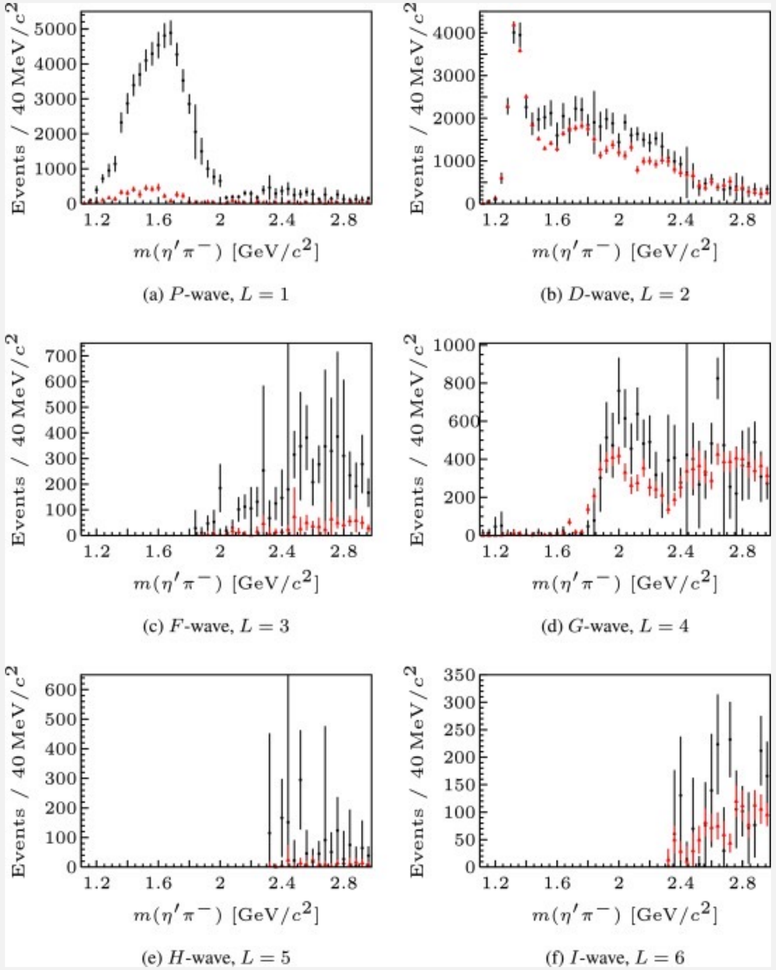
COMPASS plot

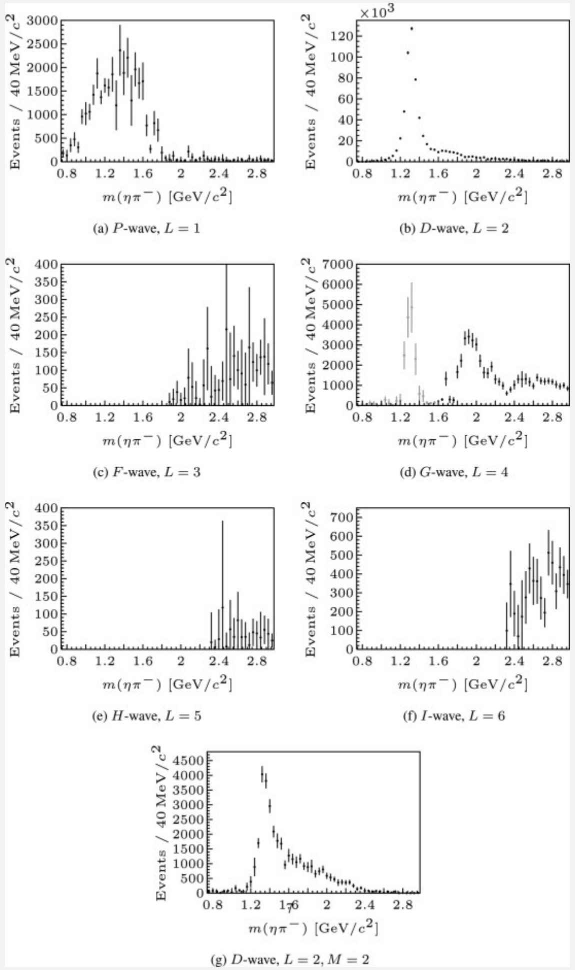


(a) $m(\eta\pi^-)$ vs. $\cos\vartheta_{GJ}$ (b) $m(\eta'\pi^-)$ vs. $\cos\vartheta_{GJ}$

COMPASS, PLB 740 303 (2015)

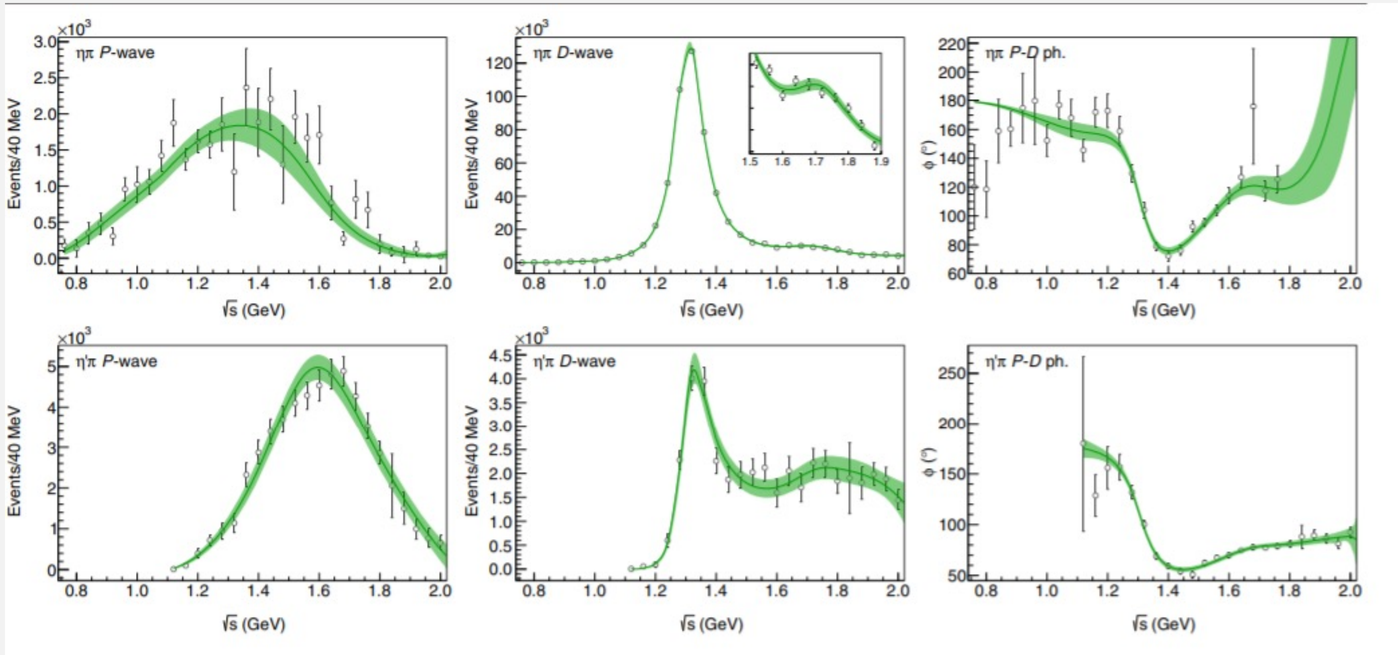
“Partial waves”



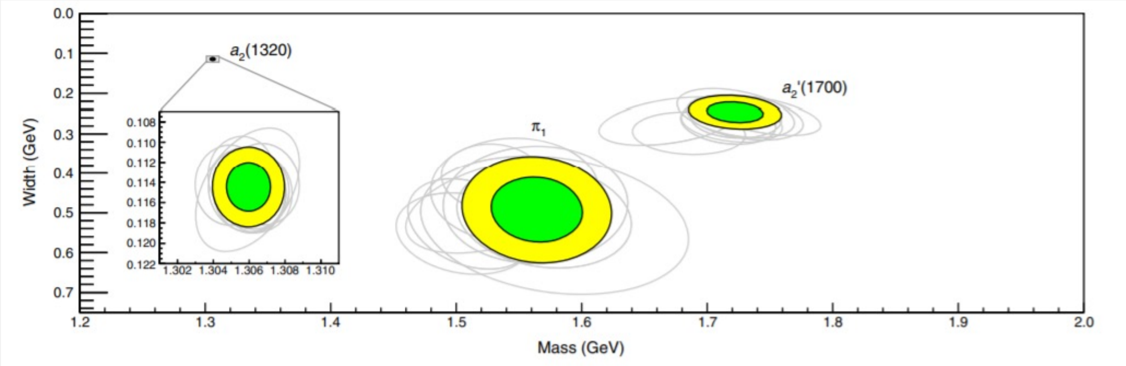


COMPASS, PLB 740 303 (2015)

Exotic in the resonance (low-energy) region

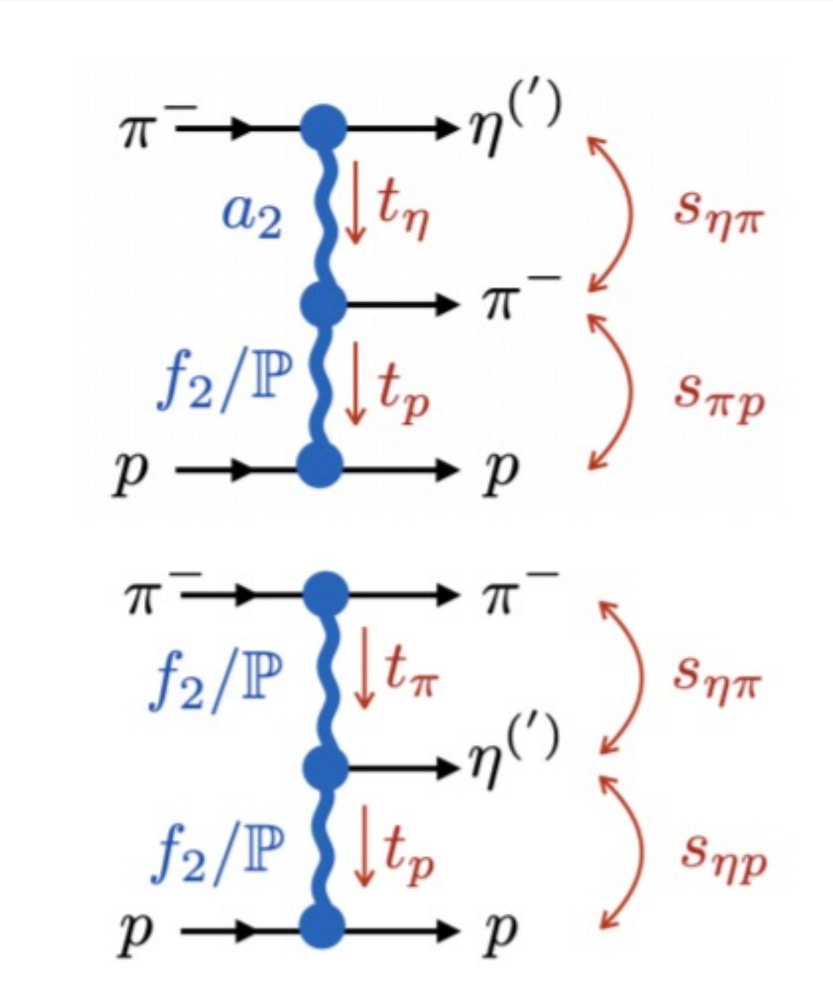


Rodas et al., PRL 122 042002 (2019)



Poles	Mass (MeV)	Width (MeV)
$a_2(1320)$	$1306.0 \pm 0.8 \pm 1.3$	$114.4 \pm 1.6 \pm 0.0$
$a_2'(1700)$	$1722 \pm 15 \pm 67$	$247 \pm 17 \pm 63$
π_1	$1564 \pm 24 \pm 86$	$492 \pm 54 \pm 102$

High-energy region model

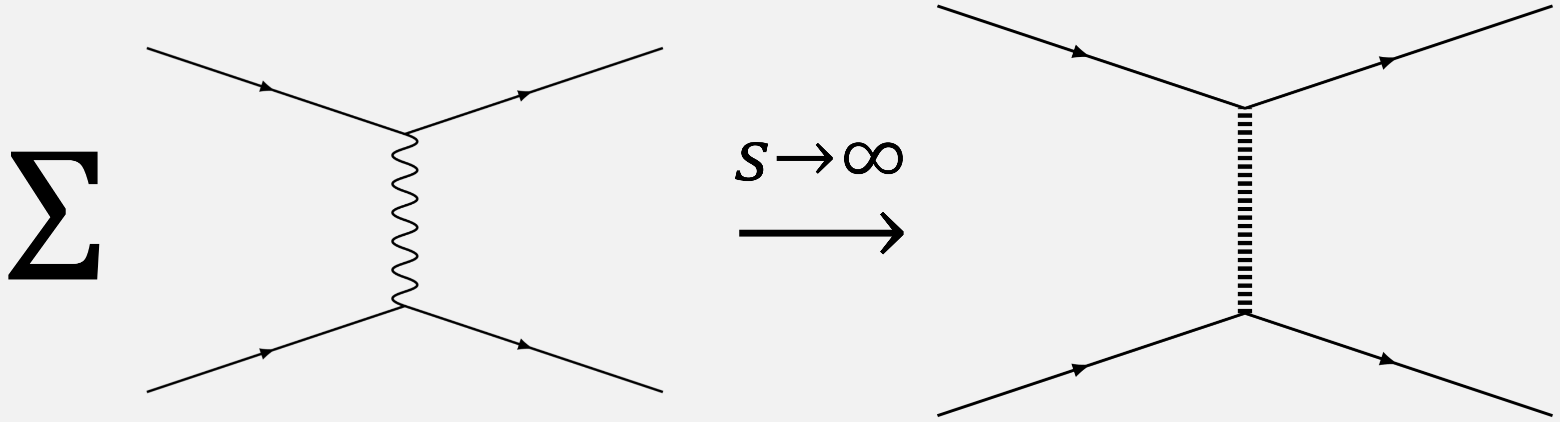


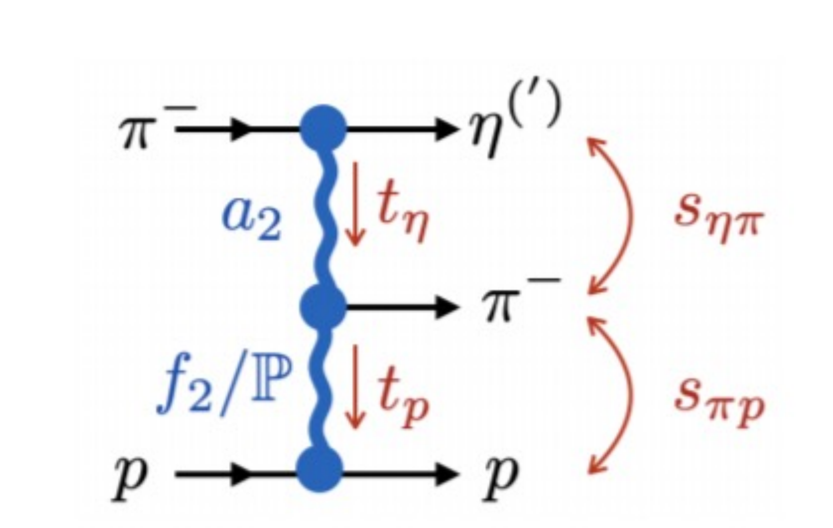
$$I_{\mathrm{Th}}(m_f, \Omega) = k(m_f)\, |A_{\mathrm{Th}}(m_f, \Omega)|^2$$

$$\begin{aligned} A_{\mathrm{Th}}(m_f, \Omega) = c_1\, A^{I}_{a_2 I\!P} + c_2\, A^{I}_{a_2 f_2} + c_3\, A^{II}_{f_2 I\!P} \\ + c_4\, A^{II}_{f_2 f_2} + c_5\, A^{II}_{I\!P I\!P} + c_6\, A^{II}_{I\!P f_2} \end{aligned}$$

Bibrzycki et al., EPJC 81 647 (2021)

Reggeons





$$\alpha_{a_2}(t) = 0.53 + 0.90\,t,$$
$$\alpha_{f_2}(t) = 0.47 + 0.89\,t,$$
$$\alpha_{\mathbb{P}}(t) = 1.08 + 0.25\,t,$$

High-energy region models

$$A^{I}_{a_2 \mathbb{P}} = T(\alpha_{a_2}(t_\eta), \alpha_{\mathbb{P}}(t_p); s_{\eta\pi}, s_{\pi p}),$$
$$A^{I}_{a_2 f_2} = T(\alpha_{a_2}(t_\eta), \alpha_{f_2}(t_p); s_{\eta\pi}, s_{\pi p}),$$
$$A^{II}_{f_2 \mathbb{P}} = T(\alpha_{f_2}(t_\pi), \alpha_{\mathbb{P}}(t_p); s_{\eta\pi}, s_{\eta p}),$$
$$A^{II}_{f_2 f_2} = T(\alpha_{f_2}(t_\pi), \alpha_{f_2}(t_p); s_{\eta\pi}, s_{\eta p}),$$
$$A^{II}_{\mathbb{P}\mathbb{P}} = T(\alpha_{\mathbb{P}}(t_\pi), \alpha_{\mathbb{P}}(t_p); s_{\eta\pi}, s_{\eta p}),$$
$$A^{II}_{\mathbb{P} f_2} = T(\alpha_{\mathbb{P}}(t_\pi), \alpha_{f_2}(t_p); s_{\eta\pi}, s_{\eta p}).$$

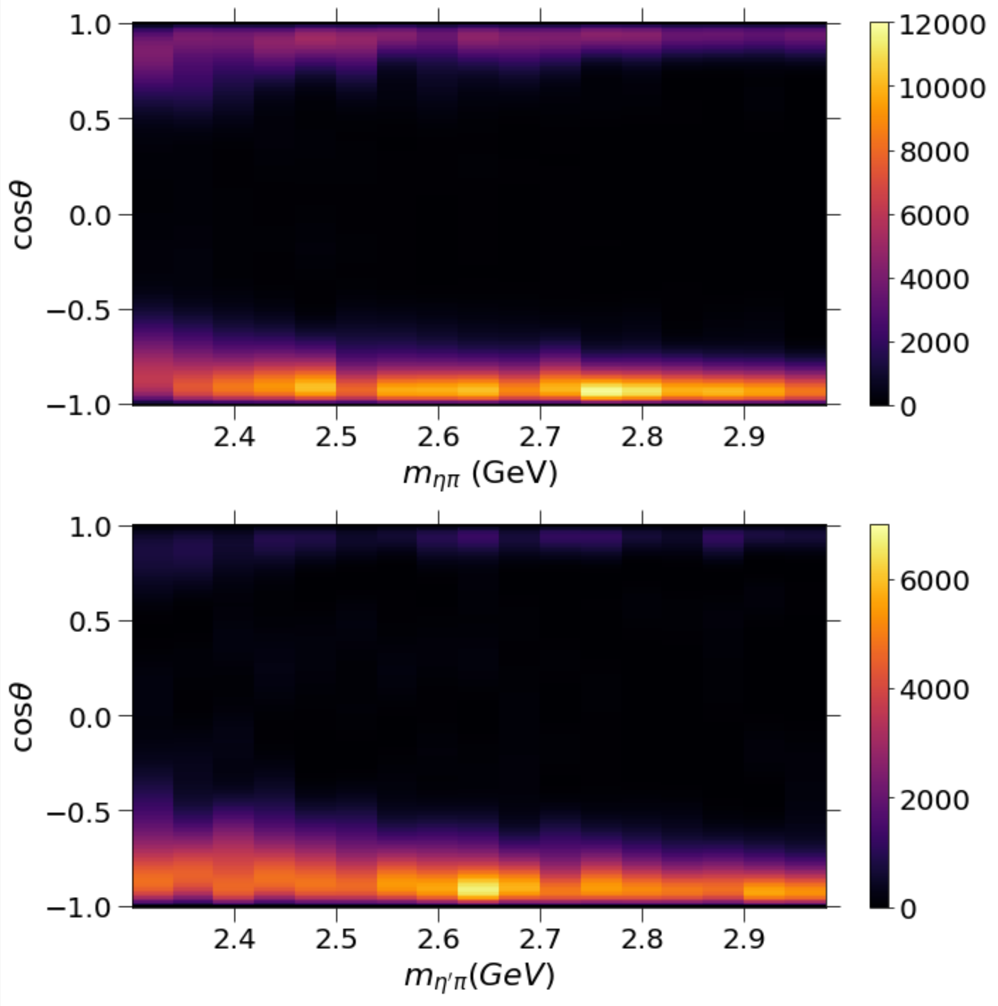
Shimada, Martin, Irving, NPB 142 344 (1978)
Shi et al., PRD 91 034007 (2015)

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

$$V(\alpha_1, \alpha_2, \kappa) = \frac{\Gamma(\alpha_1 - \alpha_2)}{\Gamma(1-\alpha_2)}\,{}_1F_1\,(1-\alpha_1, 1-\alpha_1+\alpha_2, -\kappa)$$

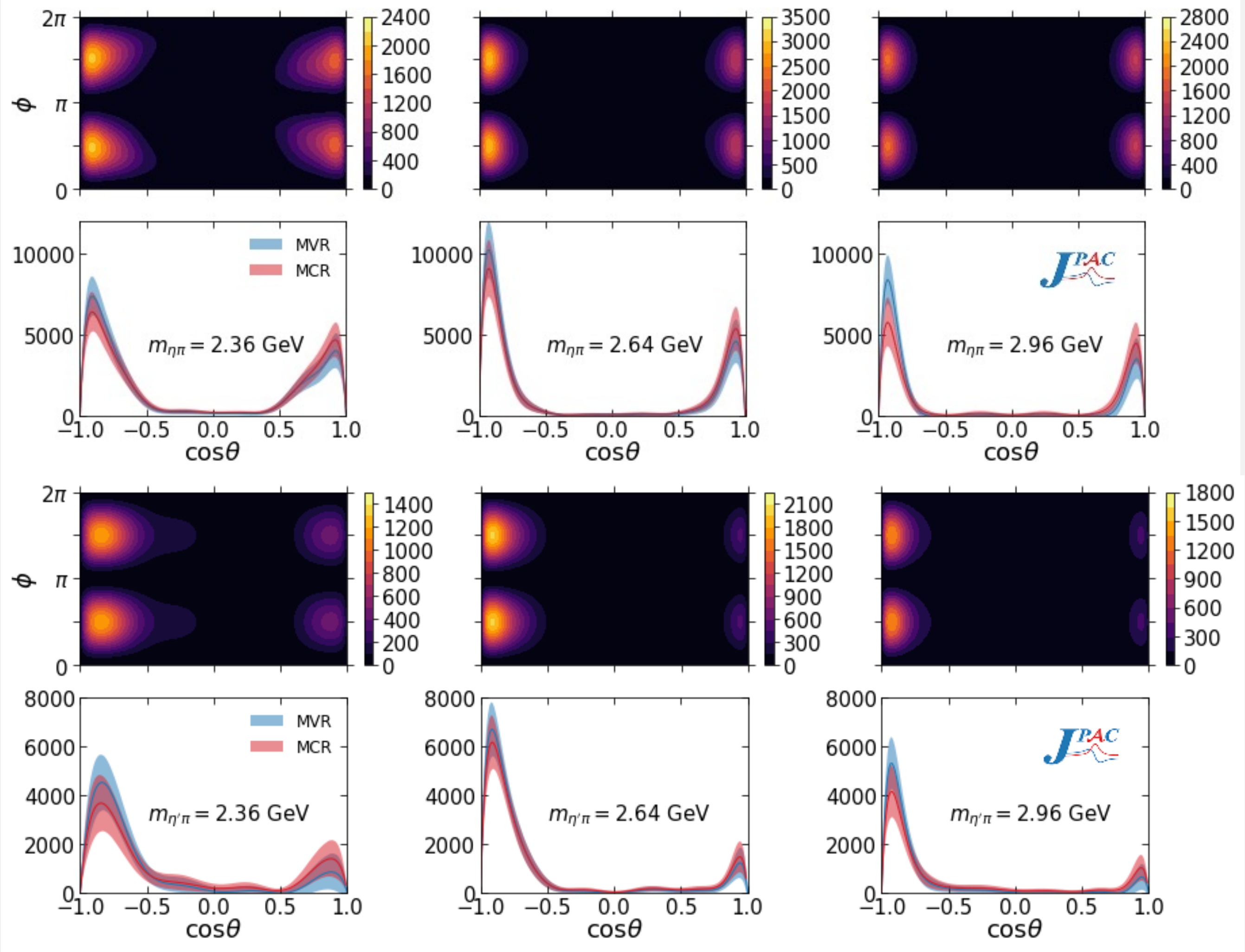
From “partial waves” to intensity distributions

$$I(m_f,\Omega) = \sum_{\epsilon=\pm} \left| \sum_{L,M} f^{\epsilon}_{LM}(m_f)\Psi^{\epsilon}_{LM}(\Omega) \right|^2$$

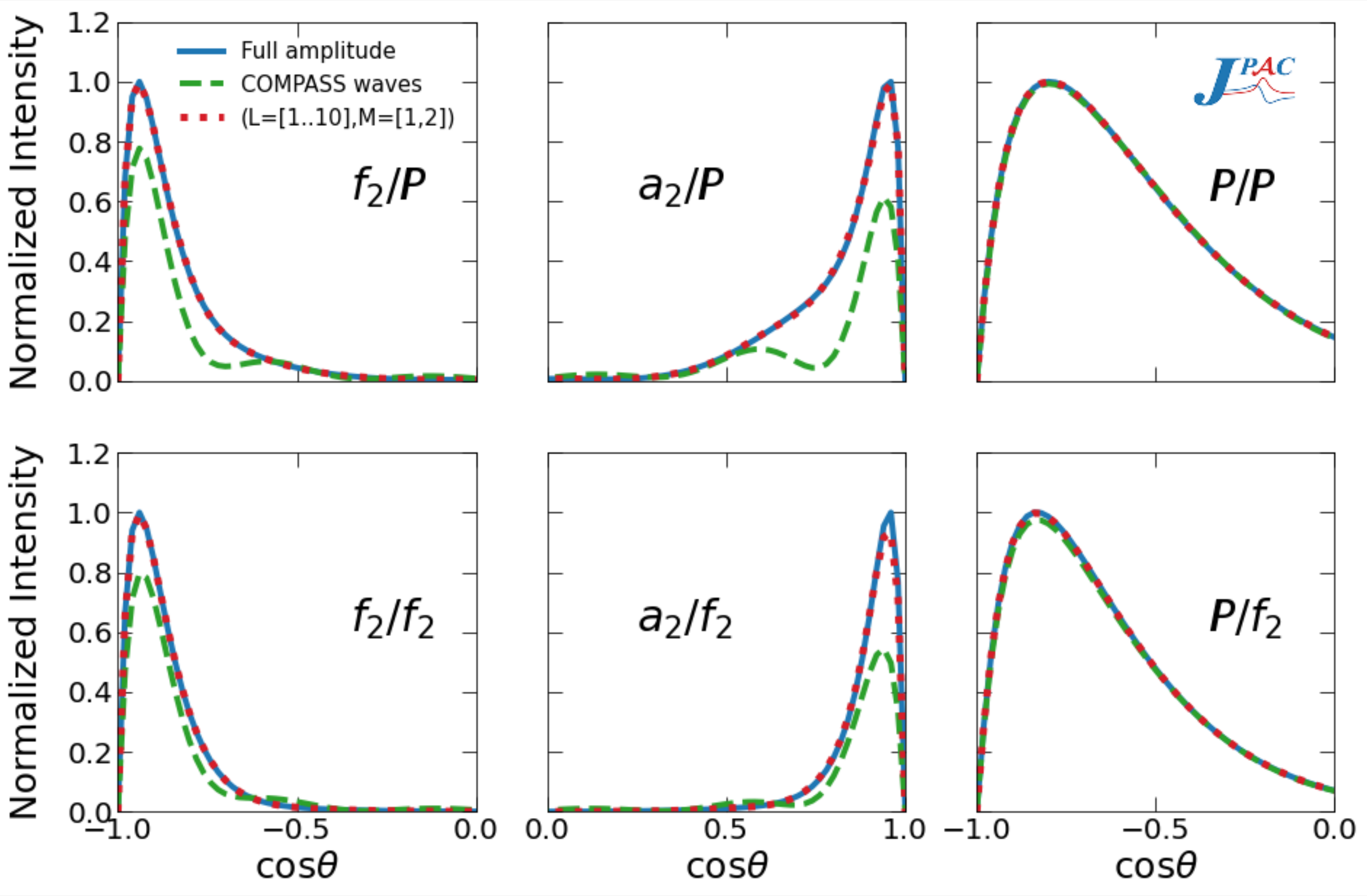


Bibrzycki et al., EPJC 81 647 (2021)

Intensity in the high-energy region



Truncation effect



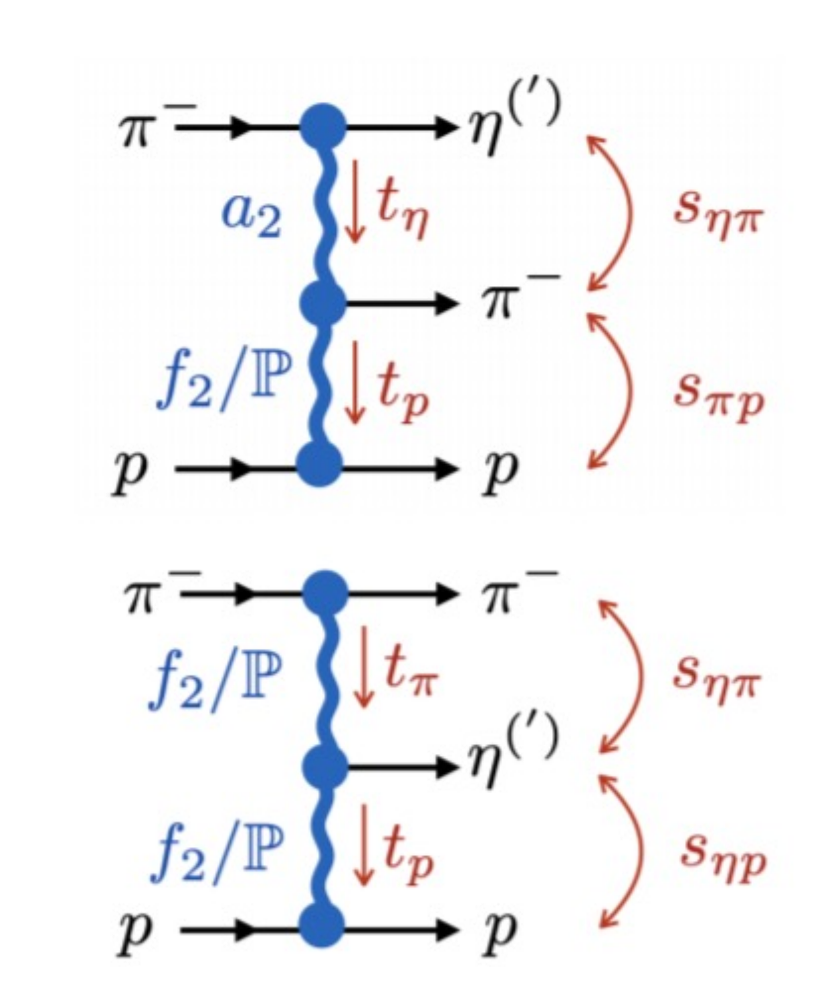
CFR. Double-Regge

Minimal models

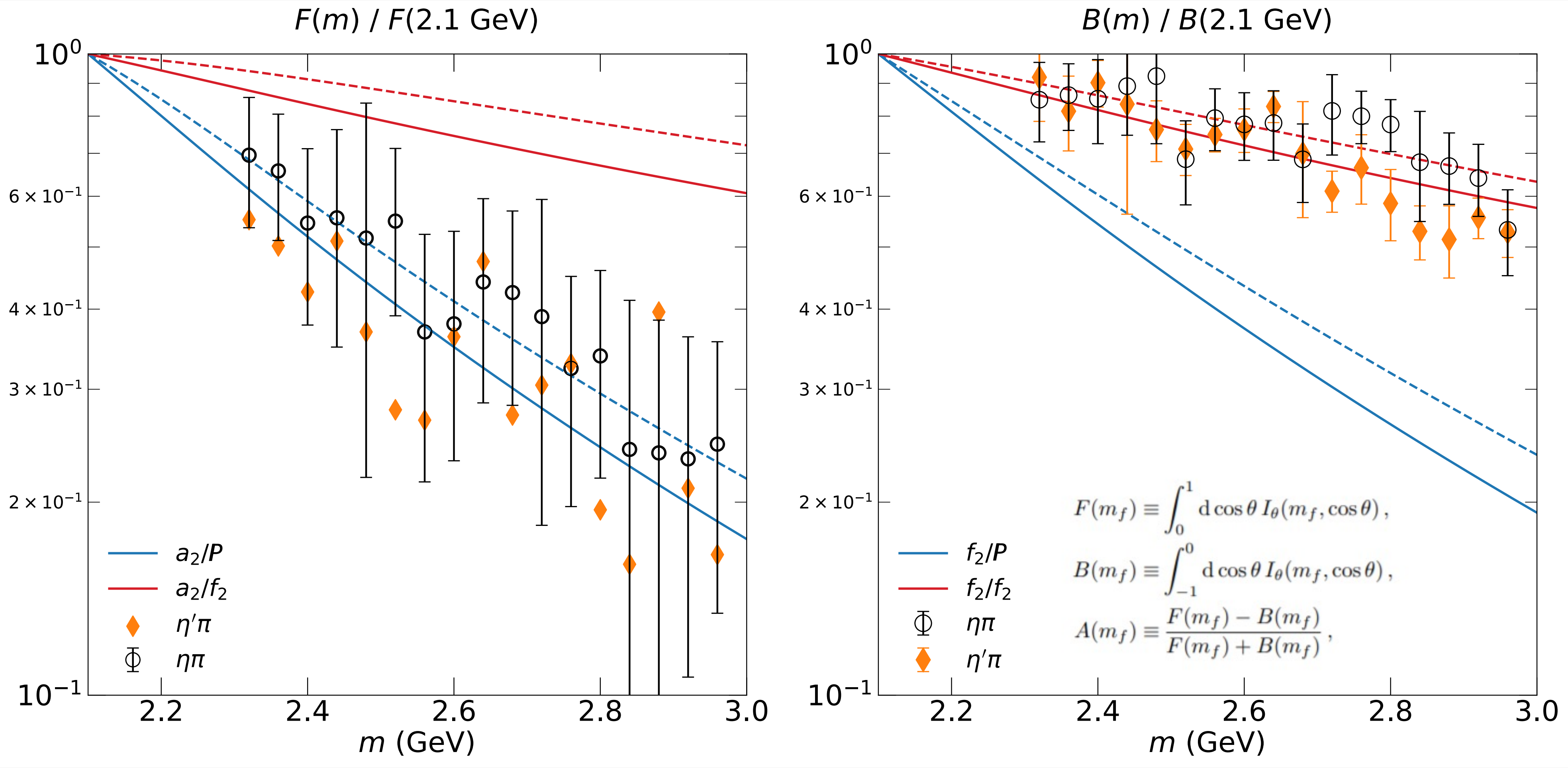
$MIN: a_2/P + a_2/f_2 + f_2/f_2$

$MIN + f/P: a_2/P + a_2/f_2 + f_2/f_2 + f_2/P$

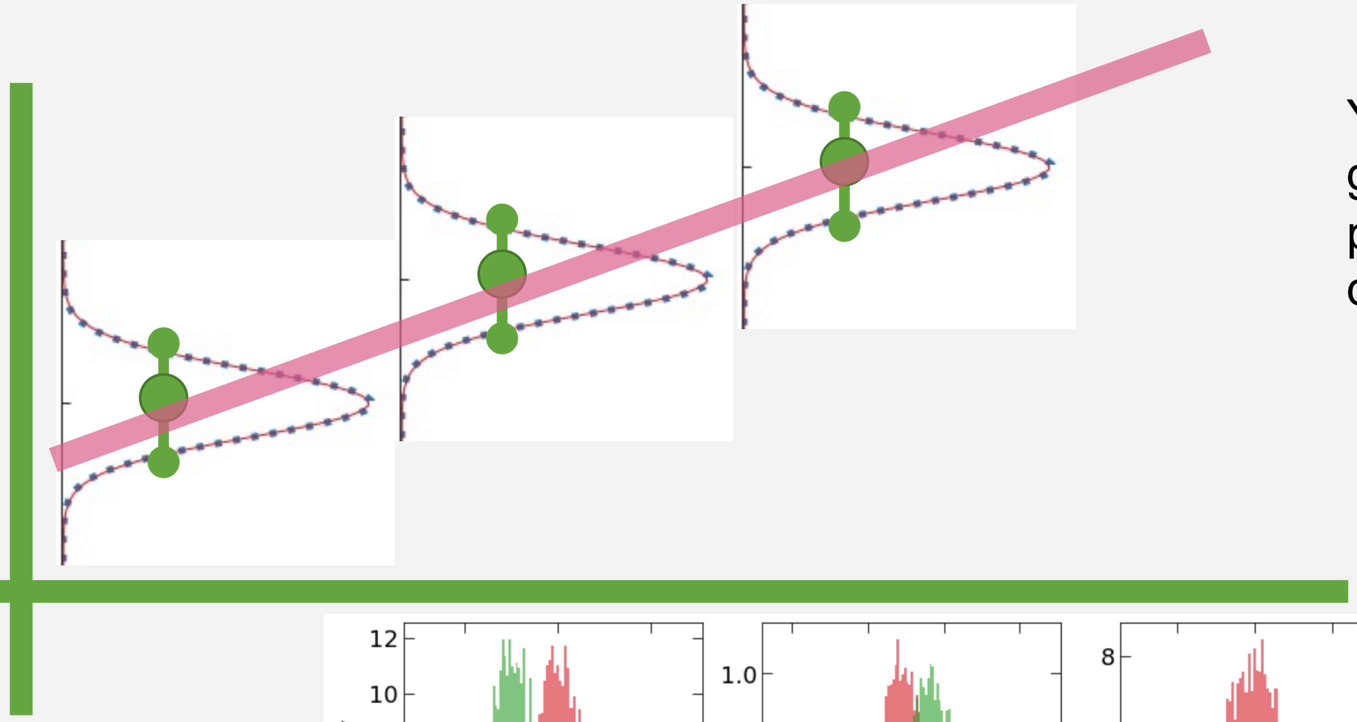
$MIN + P/P: a_2/P + a_2/f_2 + f_2/f_2 + P/P$



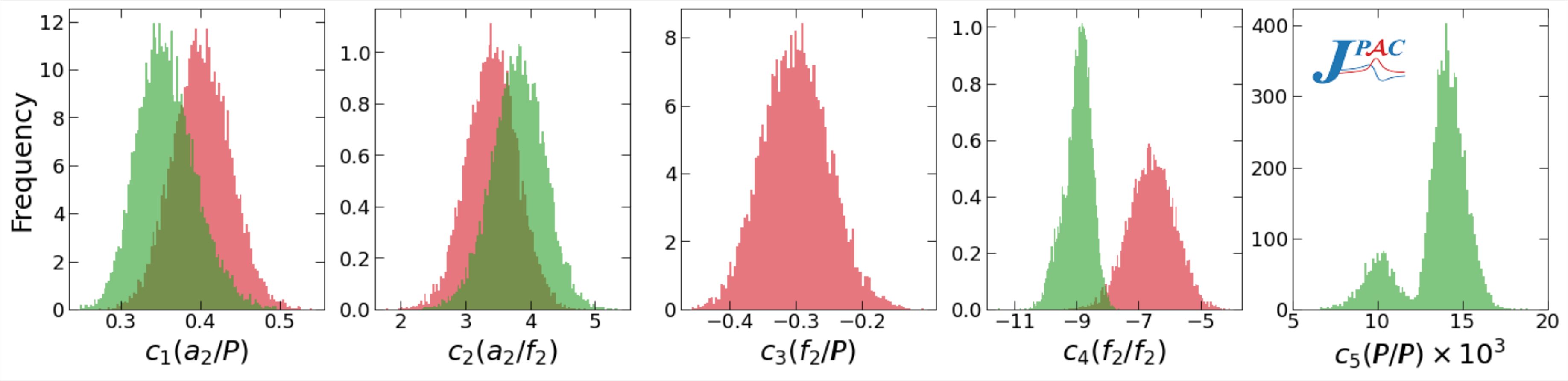
Forward and backward peaks



Bootstrap



You can run a Monte Carlo over the data, generating pseudoddata and adjust each pseudo-dataset, obtaining parameter distributions

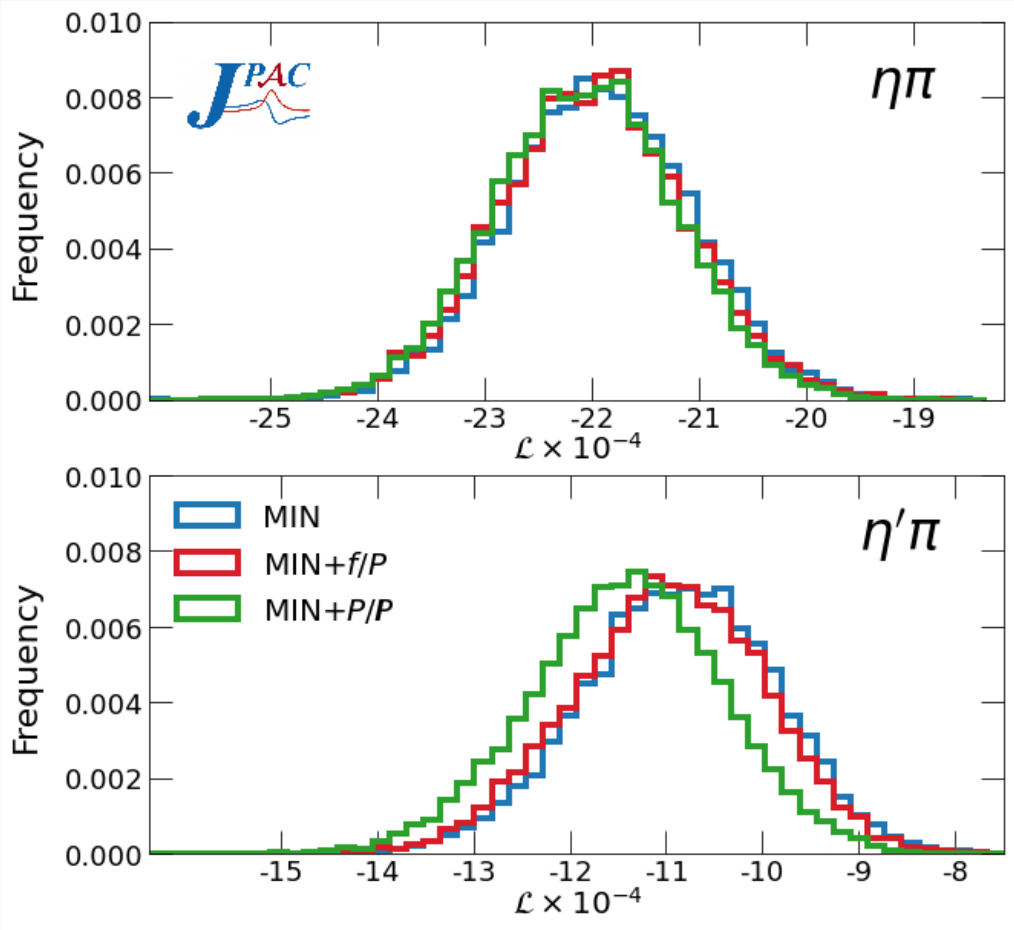


Extended log-likelihood (ELLH)

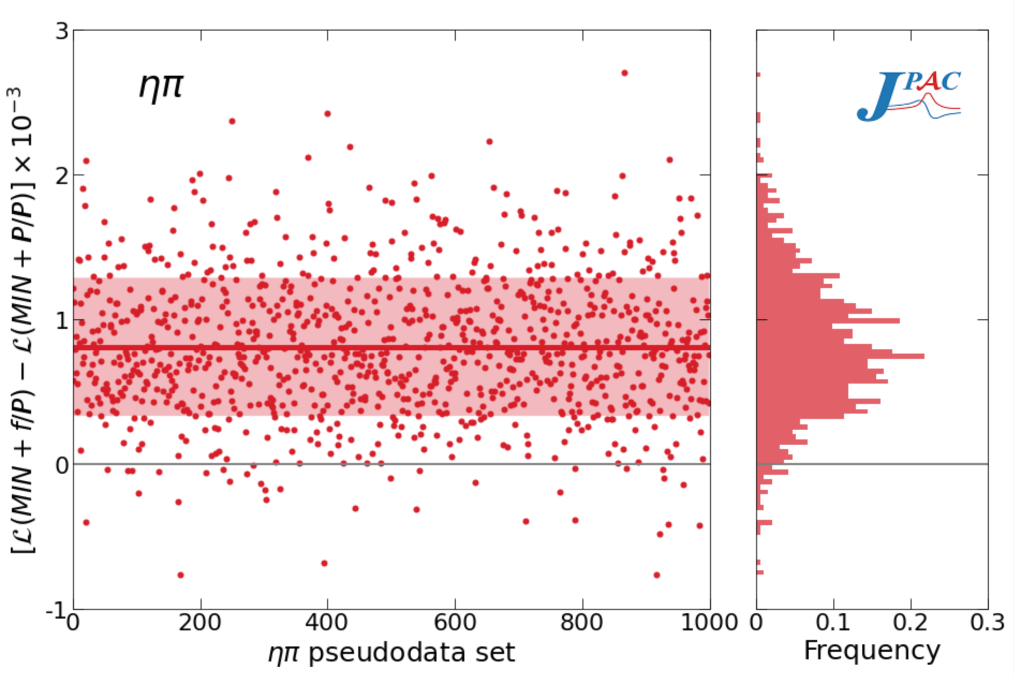
$$\mathcal{L}(\{c\}) = \sum_{m_i} \int \mathrm{d}\Omega \, \left[I_{\mathrm{T}}(m_i|\{c\}) - I_{\mathrm{E}}(m_i) \log I_{\mathrm{T}}(m_i|\{c\}) \right],$$

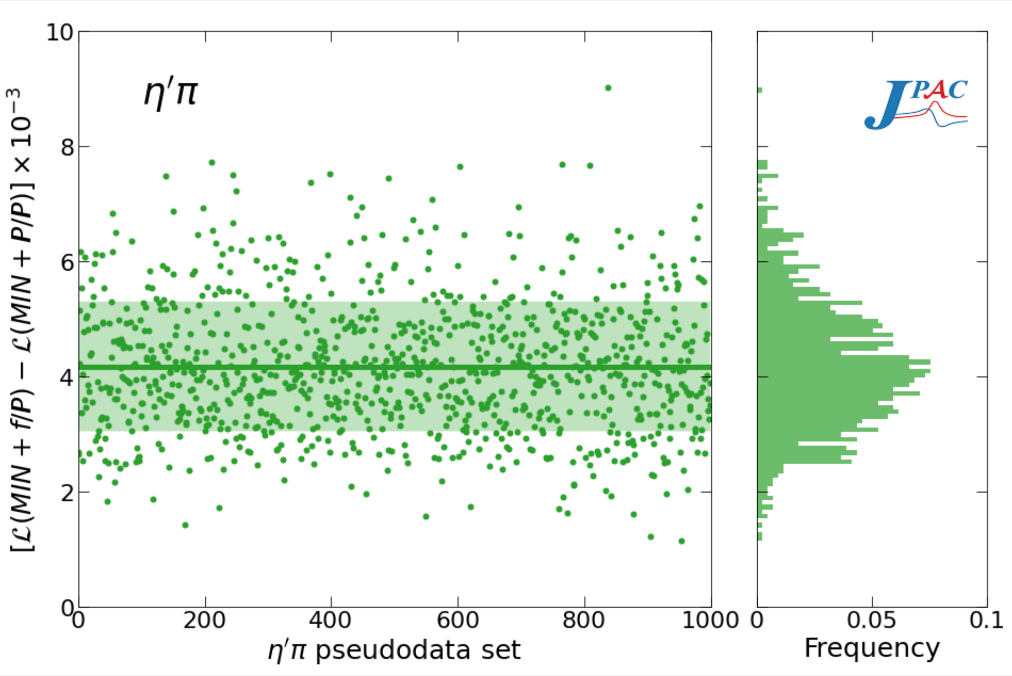
Incorporates the restriction on the total intensity

Barlow, NIMA 297 496 (1990)



Comparing ELLH





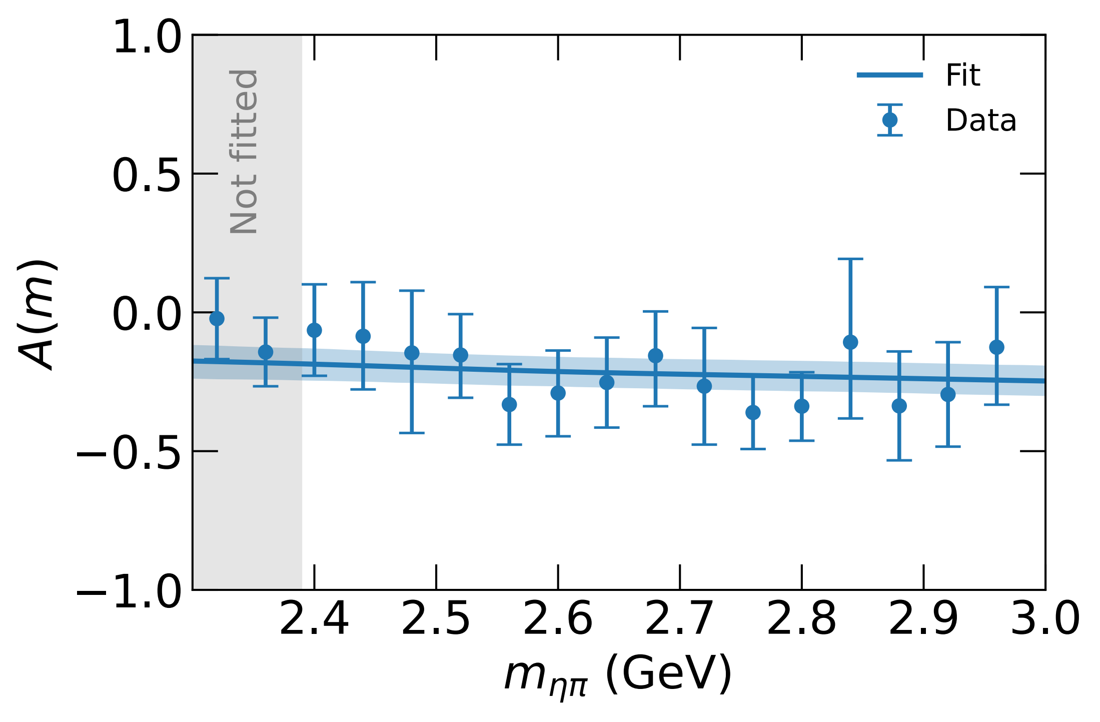
Asymmetry

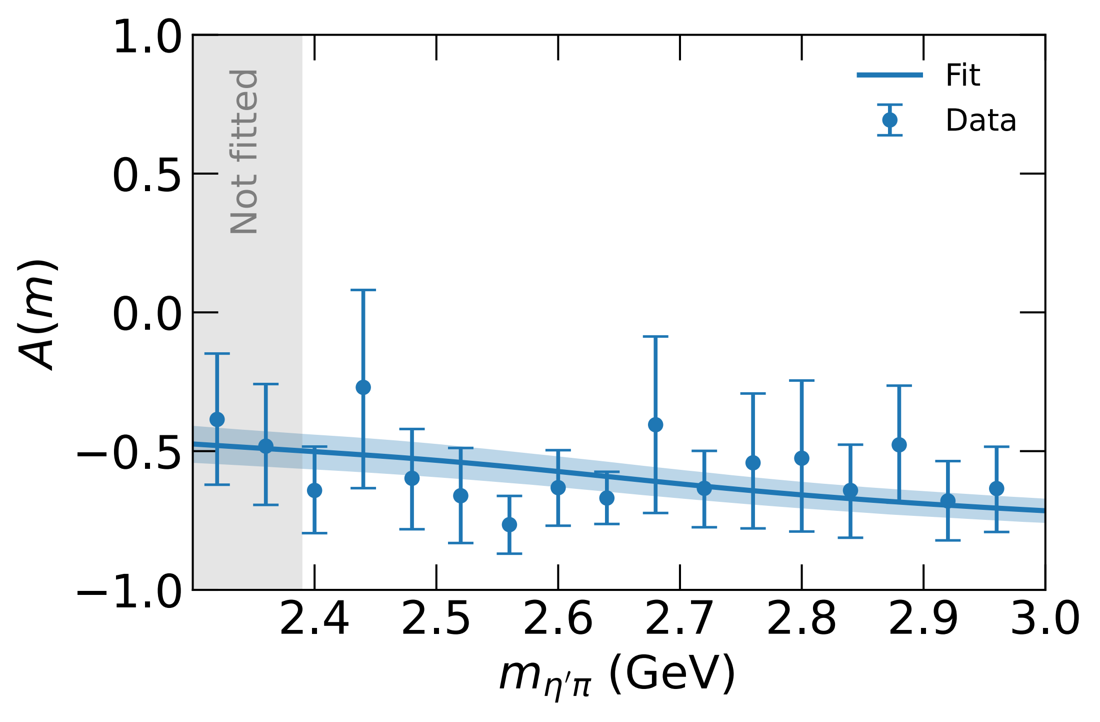
The asymmetry is proof of exotics

$$F(m_f) \equiv \int_0^1 \mathrm{d}\cos\theta \, I_\theta(m_f, \cos\theta)\,,$$

$$B(m_f) \equiv \int_{-1}^0 \mathrm{d}\cos\theta \, I_\theta(m_f, \cos\theta)\,,$$

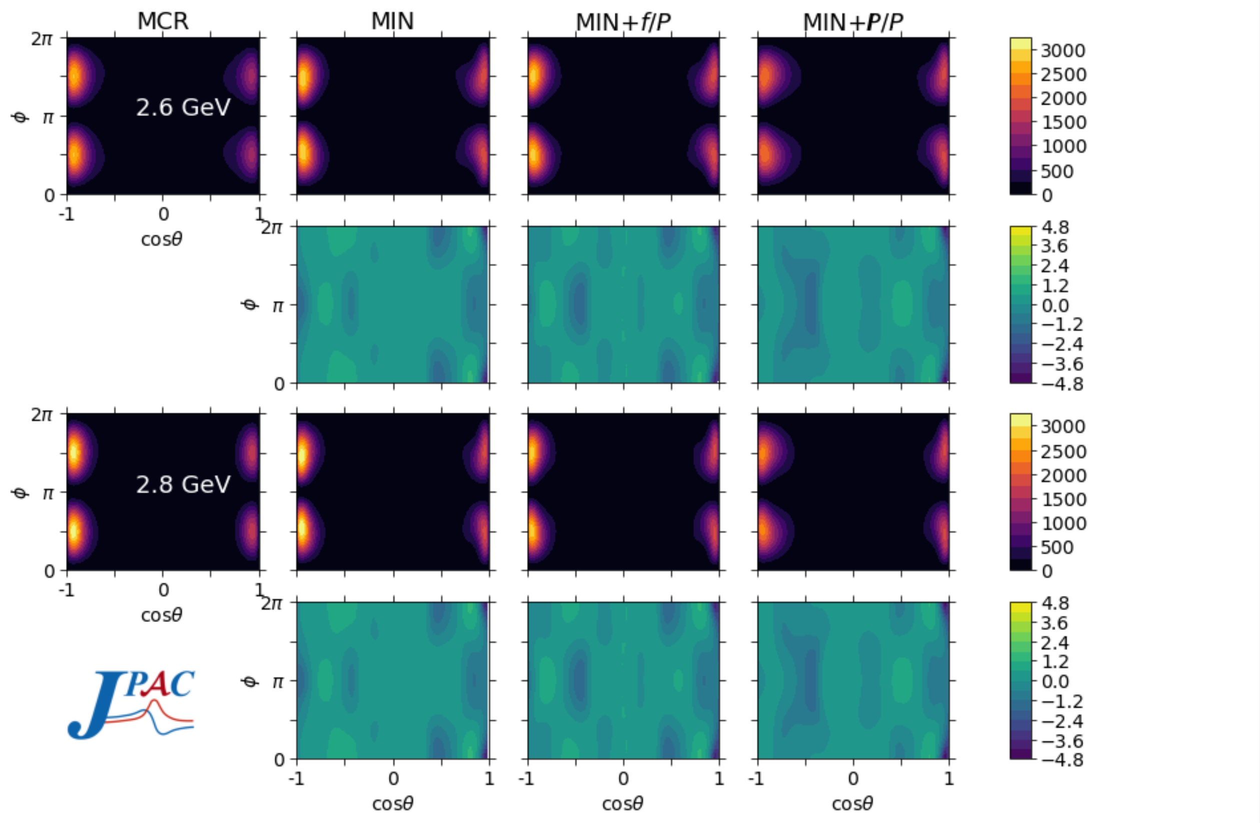
$$A(m_f) \equiv \frac{F(m_f) - B(m_f)}{F(m_f) + B(m_f)}\,,$$

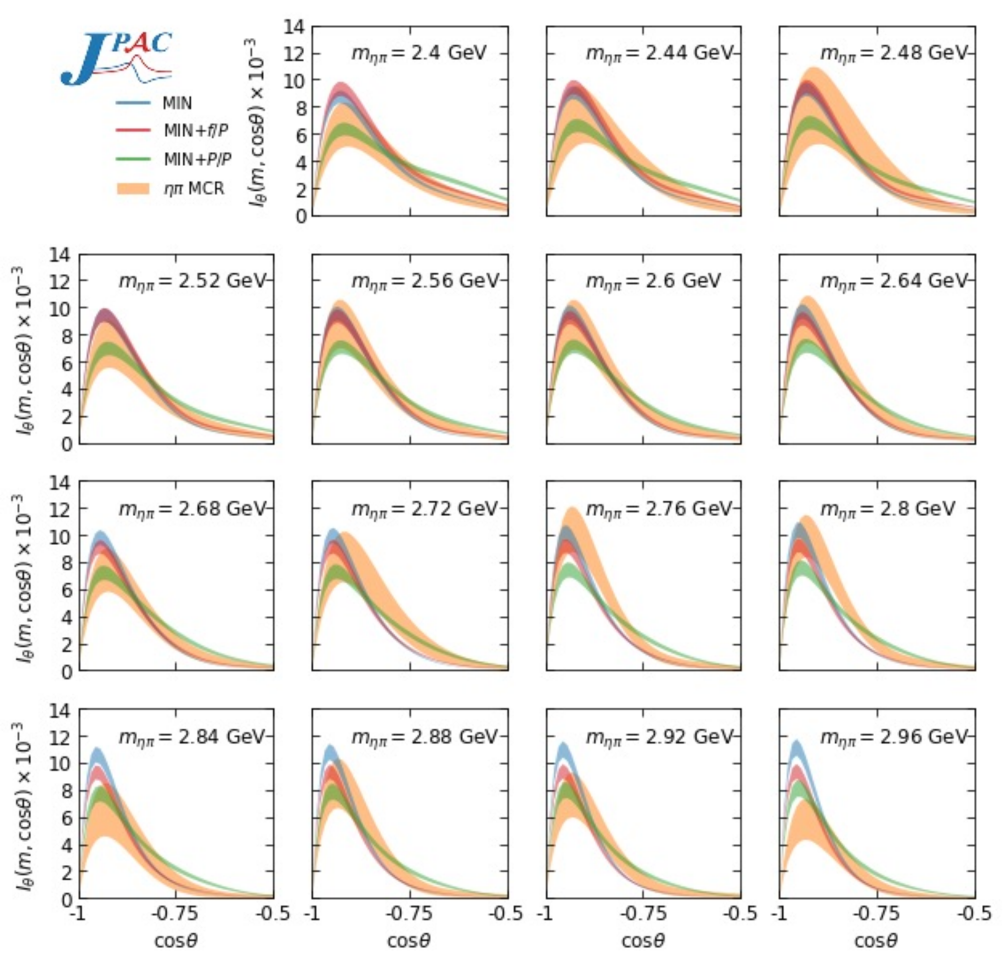




CFR. Double-Regge

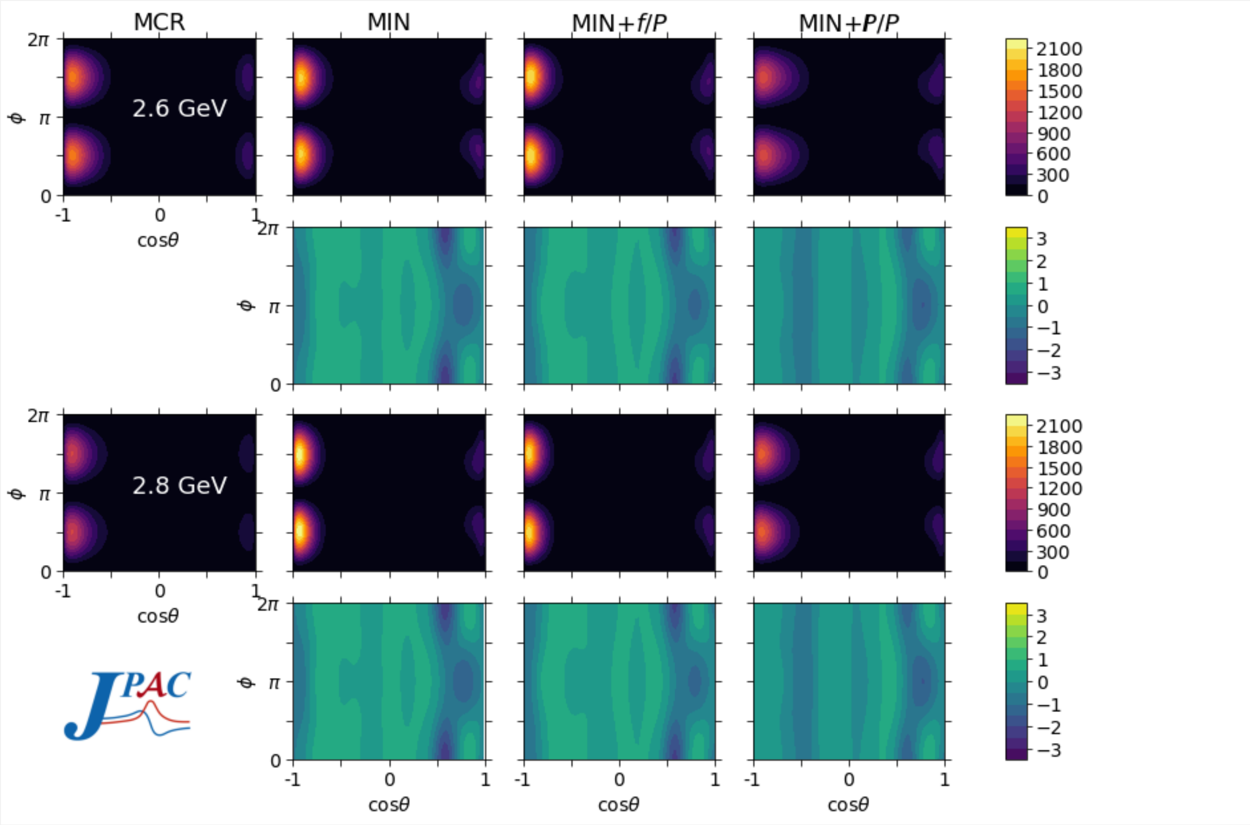
Angular distribution

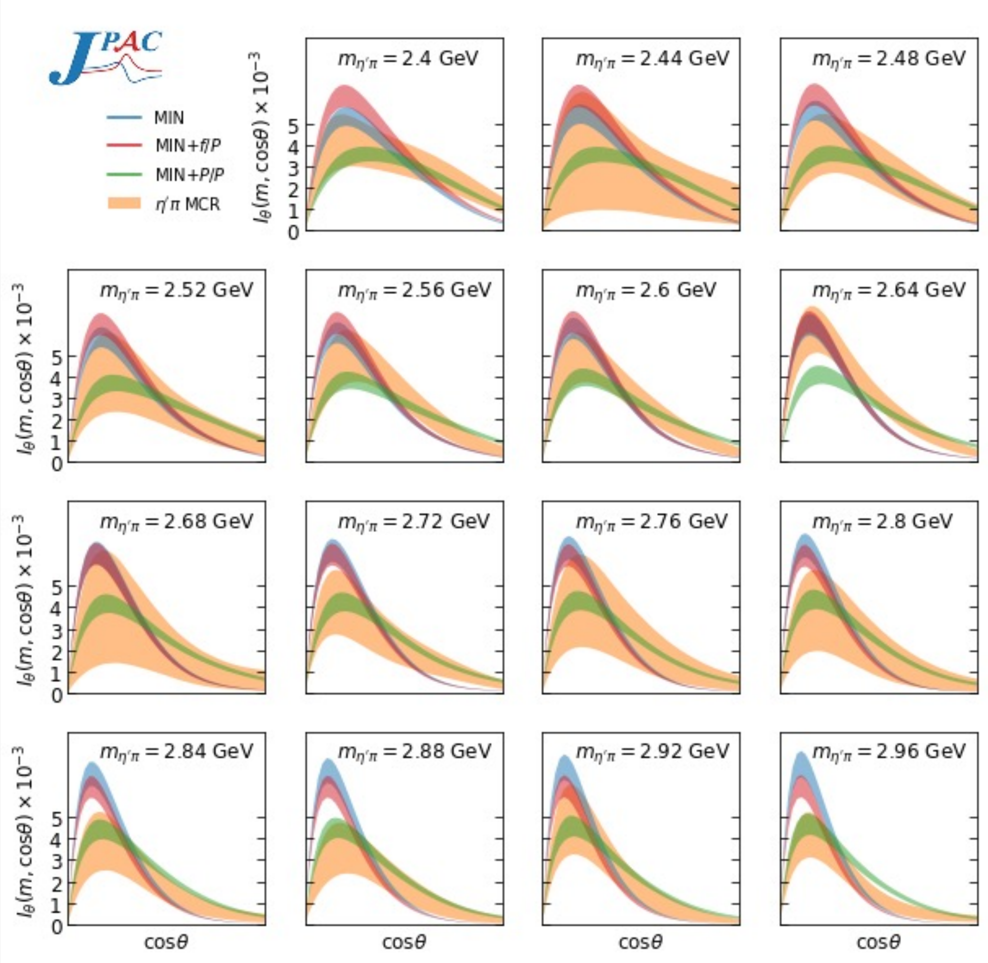




CFR. Double-Regge

Angular distribution

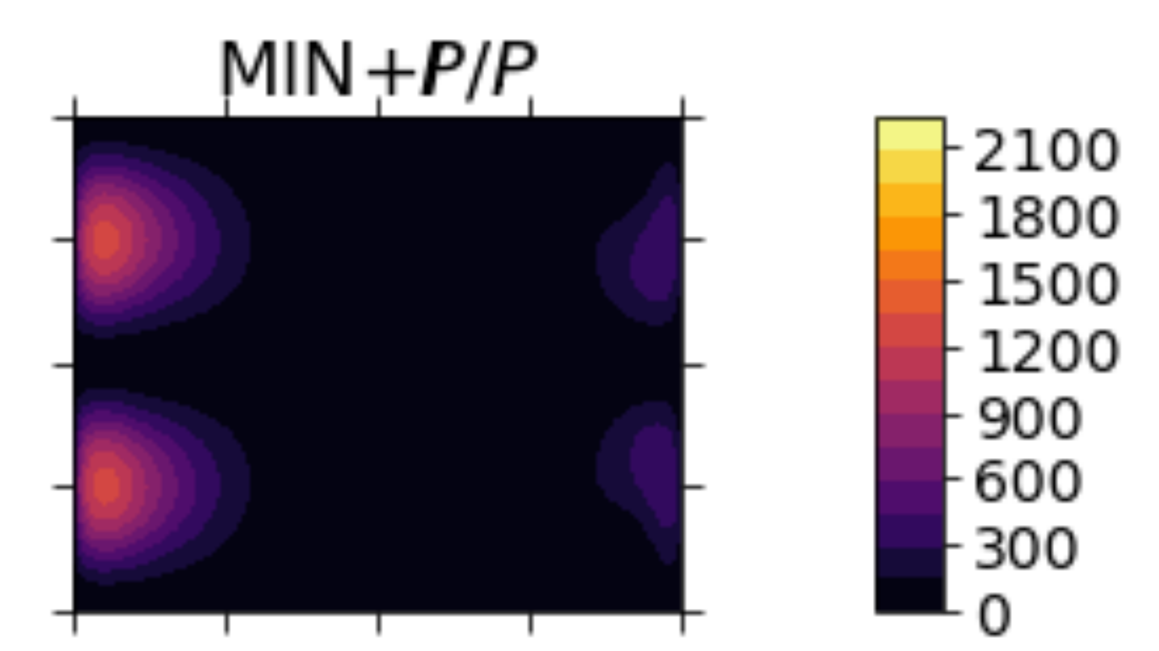




Constrained partial wave analysis (cPW)

$$\hat{\mathcal{L}}_i(\{p\}) = \int d\Omega \, [I_{\mathrm{E}}(m_i|\{p\}) - I_{\mathrm{T}}(m_i) \log I_{\mathrm{E}}(m_i|\{p\})] \, ,$$

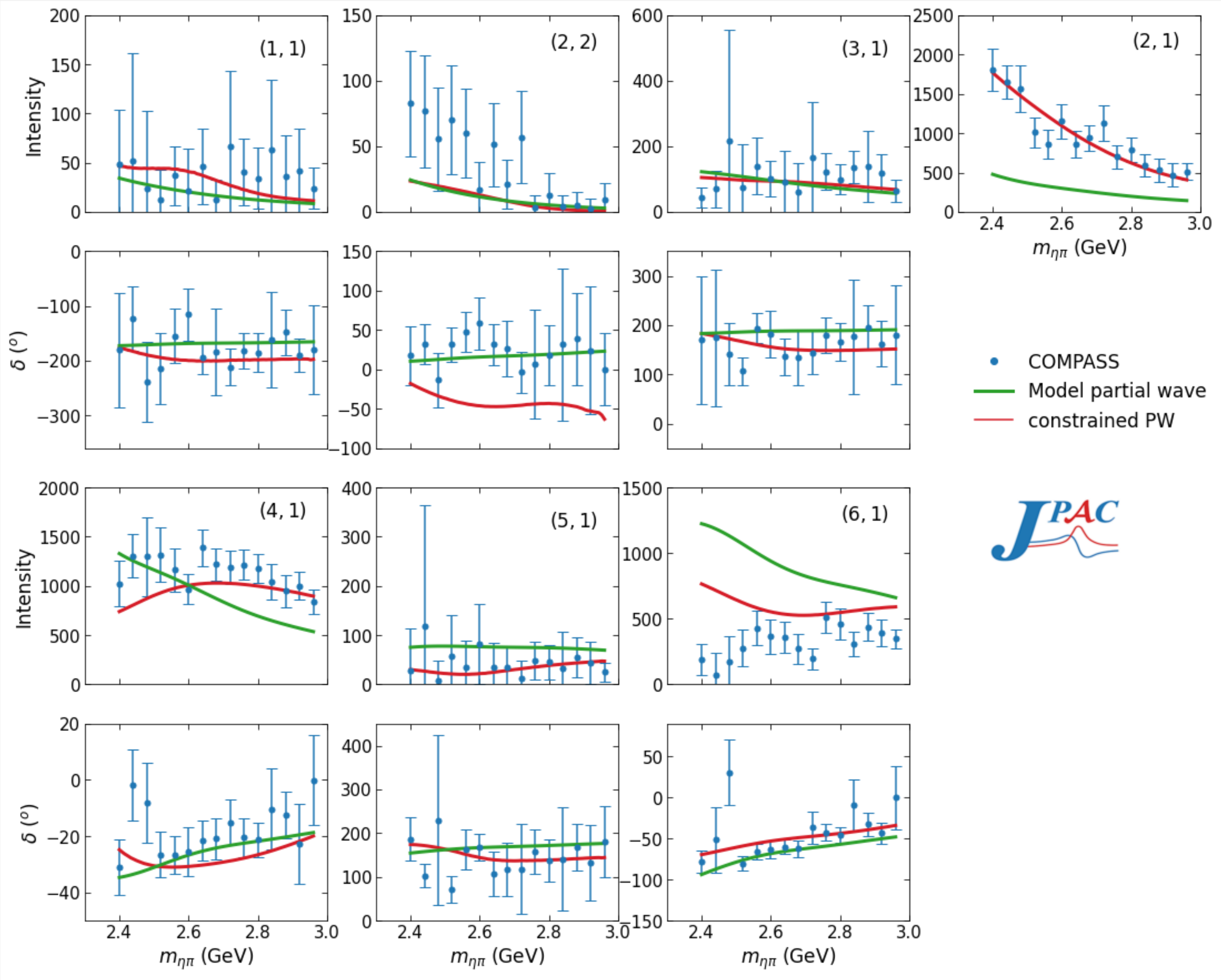
$$I_{\mathrm{E}}(m_i, \Omega|\{p\}) = \left| \sum_{L,M} p_{LM}(m_i) \Psi^{+}_{LM}(\Omega) \right|^2$$



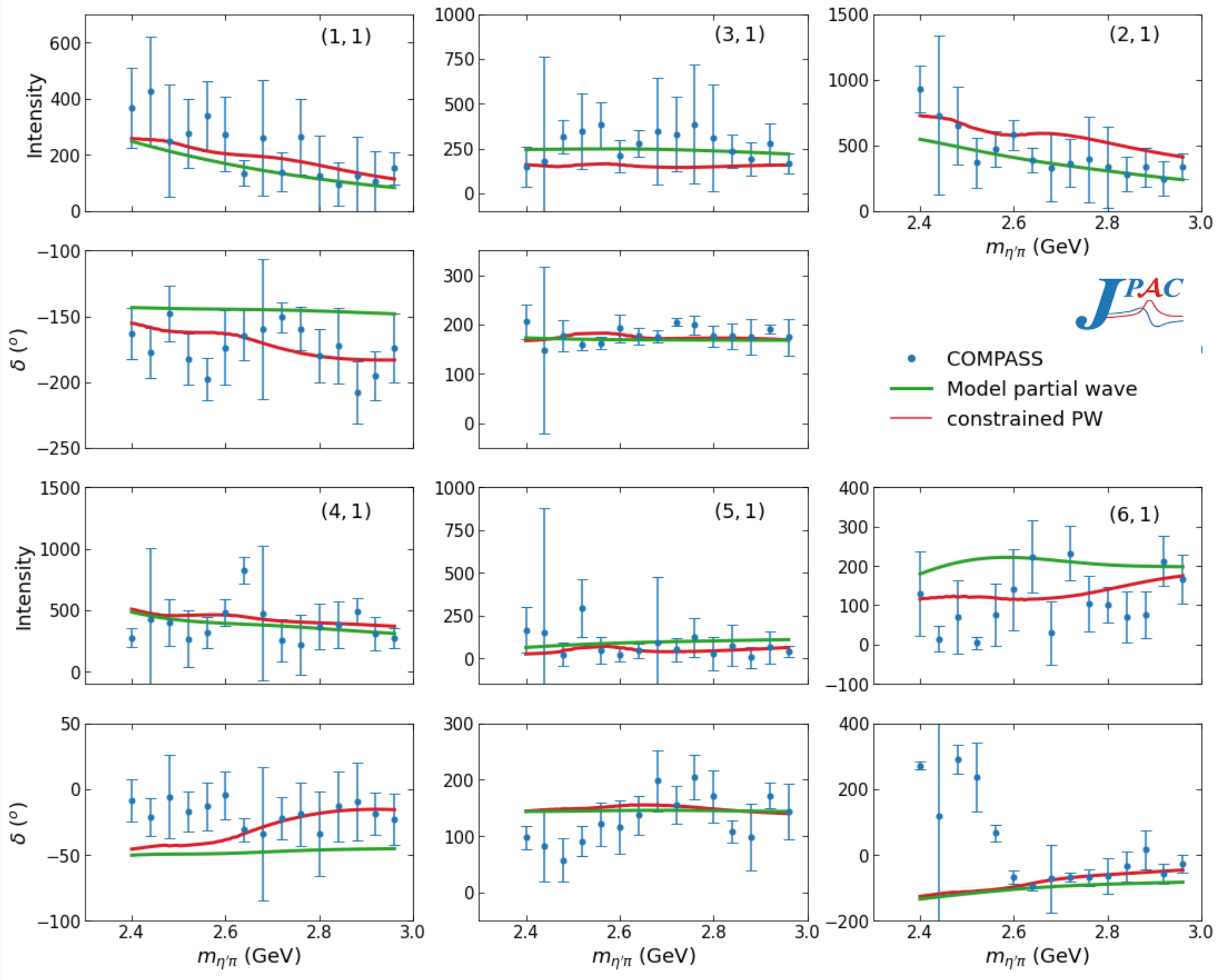
We treat theory as experimental data and we extract the partial waves under the Same approximations made by COMPASS

cPW ηπ

$$\hat{\mathcal{L}}_i(\{p\}) = \int d\Omega \, [I_{\mathrm{E}}(m_i|\{p\}) - I_{\mathrm{T}}(m_i) \log I_{\mathrm{E}}(m_i|\{p\})] \,,$$



cPW η’π


(1, 1)
(3, 1)
(2, 1)
(4, 1)
(5, 1)
(6, 1)
Intensity
δ (°)
$m_{\eta'\pi}$ (GeV)
COMPASS
Model partial wave
constrained PW

Results

$\eta\pi$ and $\eta'\pi$ at "high" energy

- *Golden channels to search exotic quantum numbers*

Above 2.5 GeV

- *$\eta\pi$ intensity can be described by four double.Regge exchanges: a_2/P, a_2/f_2, f_2/f_2 y f_2/P o P/P. Details in Bibrzycki et al., EPJC 81 647 (2021)*

Pomeron is essential for cos θ ~ -1 data

- *Gluonic degrees of freedom in $\eta'\pi$, potentially related to hybrids*

Results

Asymmetry

- *Proves the existence of exotics*

The dangers of partial wave truncation

- *Highlighted at high-energy because of Reggeons*
- *Shown by the cPW analysis*

The danger of not comparing “apples” to “apples”

- *If we had fitted COMPASS partial waves directly we would have been wrong*