

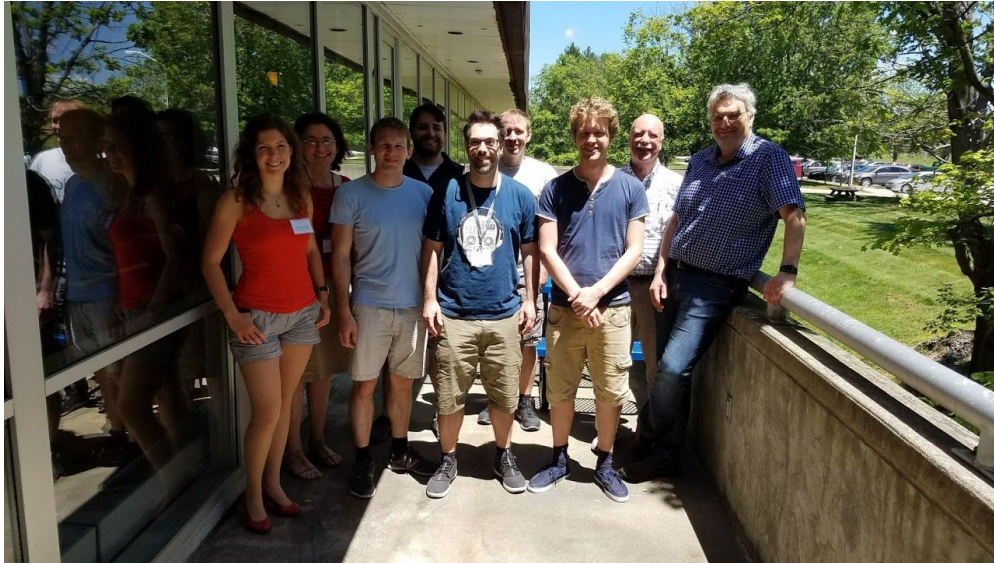
# *J*PAC activity update

Jannes Nys



# JPAC collaboration

- We aim at developing new **theoretical tools**, to get insight on QCD using first principles of QFT (unitarity, analyticity, crossing symmetry, low and high energy constraints,...) to *extract the physics out of the data*
- Many ongoing projects (both for meson and baryon spectroscopy, and for high energy observables), with a particular attention to producing complete reaction models for the **golden channels in exotic meson searches**



# Overview

- Various reactions
- Predictions at JLab energies (photoproduction)
- Two **main questions** about the production process:
  - Which exchanges dominate at JLab energies?
  - Are these processes factorizable?

$$\gamma N \rightarrow \pi^{(0,\pm)} N$$

$$\gamma N \rightarrow \pi \Delta$$

$$\gamma N \rightarrow \omega N$$

$$\gamma N \rightarrow \eta N$$

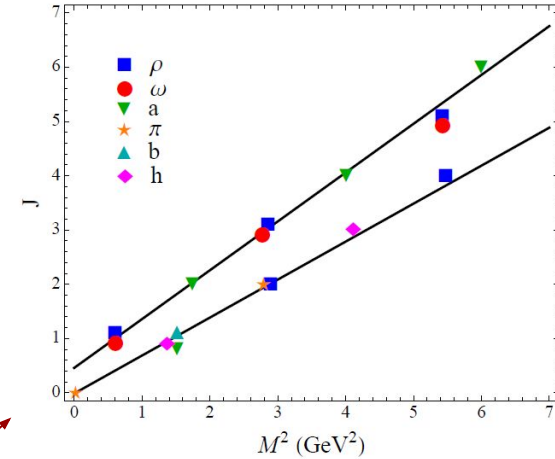
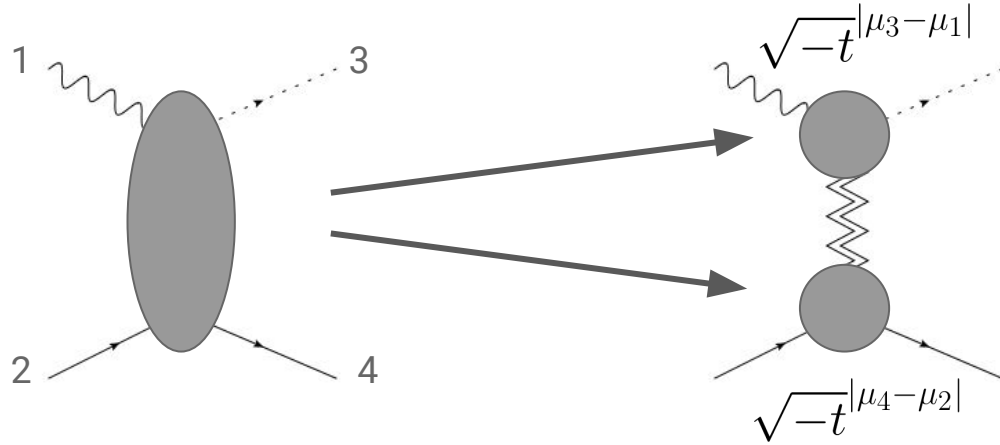
$$\gamma N \rightarrow \rho^0 N$$

$$\gamma N \rightarrow \phi N$$

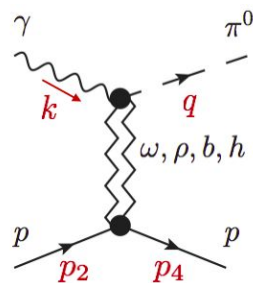
- Unitary models for PWA of exotic channels

# Factorization at high energies

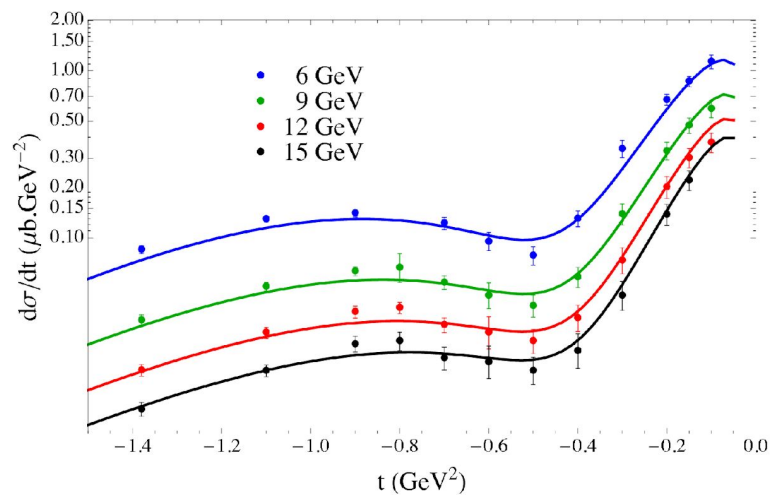
- Regge poles: coupled-channel effect at high energies
- Contribution from **photon** and **baryon** vertex
- Suppresses amplitudes in forward direction ( $t=0$ )



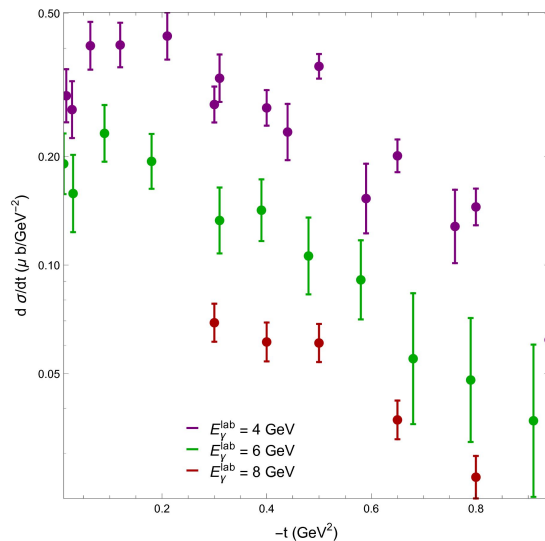
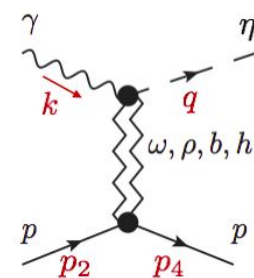
$$A_{\mu_4 \mu_3 \mu_2 \mu_1}(s, t) = \beta_{\mu_3 \mu_1}^{\text{top}}(t) \beta_{\mu_4 \mu_2}^{\text{bottom}}(t) R(s, t) s^{\alpha(t)}$$

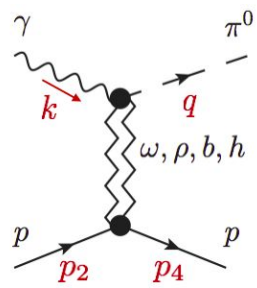


$$\gamma N \rightarrow \pi^0 N$$



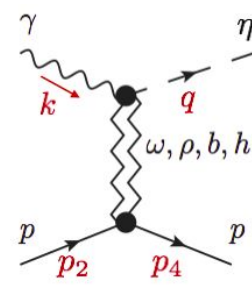
$$\gamma N \rightarrow \eta N$$





$$\gamma N \rightarrow \pi^0 N$$

$$\gamma N \rightarrow \eta N$$

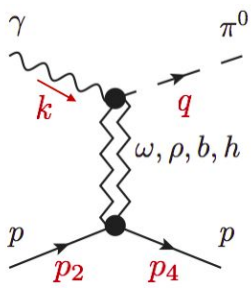


- Beam asymmetry is sensitive to **naturality**:

$$\Sigma = \frac{\sigma_{\perp} - \sigma_{\parallel}}{\sigma_{\perp} + \sigma_{\parallel}} = \frac{|\rho + \omega|^2 - |b + h|^2}{|\rho + \omega|^2 + |b + h|^2}$$

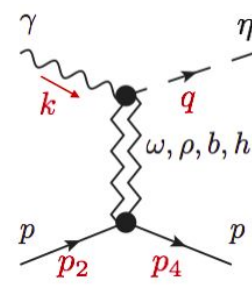
$$\Sigma = +1 \quad : \quad \rho, \omega$$

$$\Sigma = -1 \quad : \quad b, h$$

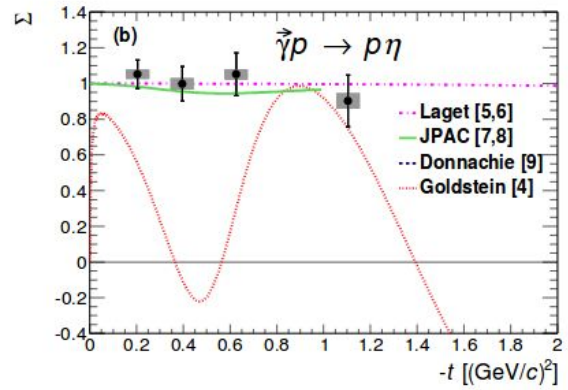
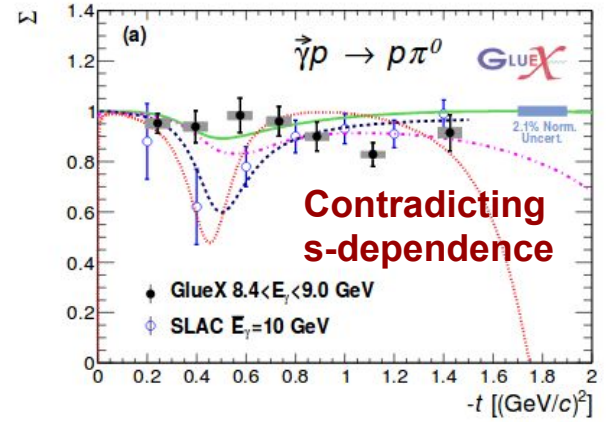


$$\gamma N \rightarrow \pi^0 N$$

$$\gamma N \rightarrow \eta N$$



- Beam asymmetry is sensitive to **naturality**: natural exchanges dominate!



# Extension to $\eta'$ photoproduction

$$\Sigma^{(\prime)} = \frac{\sigma_{\perp}^{(\prime)} - \sigma_{\parallel}^{(\prime)}}{\sigma_{\perp}^{(\prime)} + \sigma_{\parallel}^{(\prime)}} \eta^{(\prime)}$$

- Natural exchanges dominate:  $\eta$ - $\eta'$  mixing angle cancels

$$\Sigma = \frac{|\rho + \omega|^2 - |b + h|^2}{|\rho + \omega|^2 + |b + h|^2} = \Sigma'$$

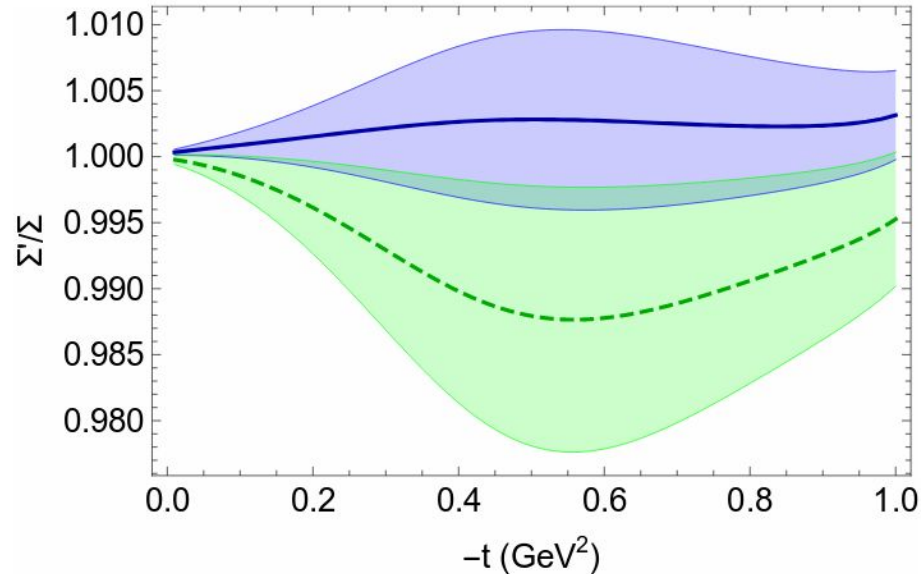
- Hidden strangeness exchanges or strong deviations from quark model

$$\Sigma = \frac{|\rho + \omega + \phi|^2 - |b + h + h'|^2}{|\rho + \omega + \phi|^2 + |b + h + h'|^2} \neq \Sigma'$$



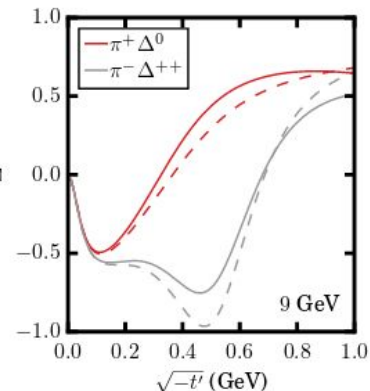
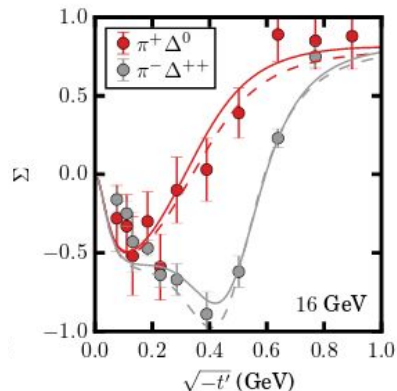
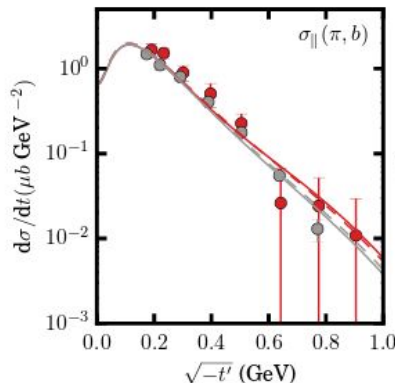
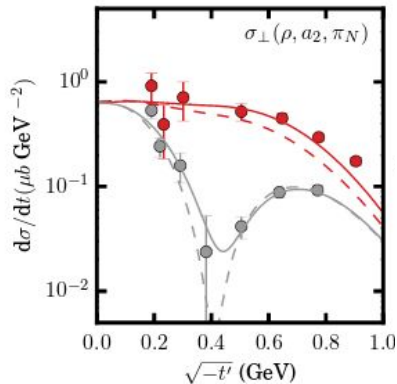
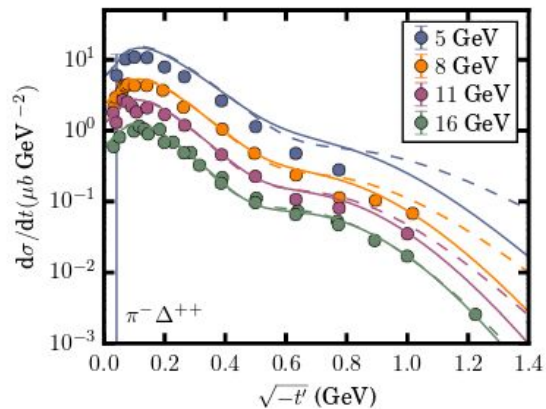
# Extension to $\eta'$ photoproduction

- Unnatural components have little effect
- $\Phi$ ,  $h'$  components are subleading



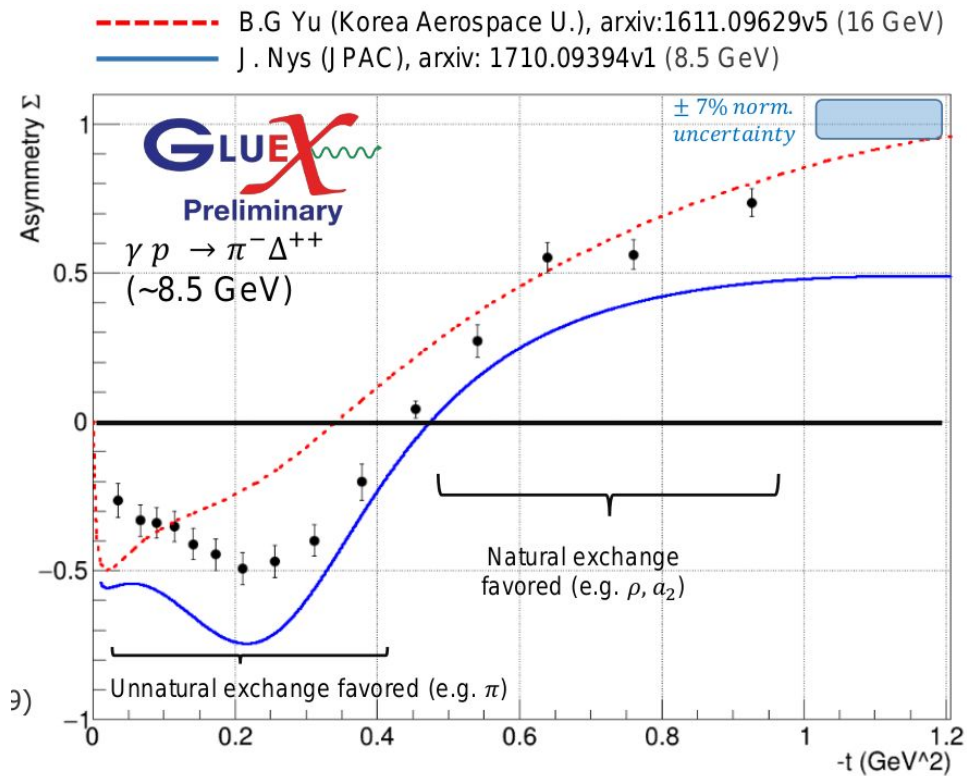
# $\gamma N \rightarrow \pi \Delta$ charge exchange

- Dominated by charged pion exchanges
- Model includes
  - Absorbed pion exchange
  - $\rho$ ,  $a_2$  exchange (cuts)



# $\gamma N \rightarrow \pi \Delta$ charge exchange

- Comparison to preliminary GlueX data @ 8.5 GeV (J.Zarling, DNP 2017)

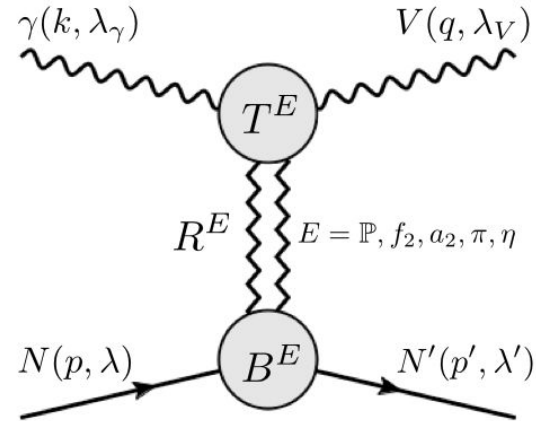
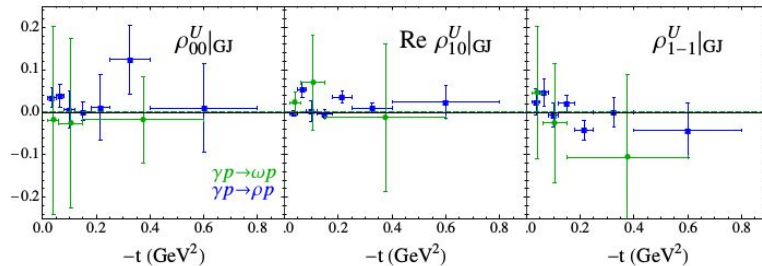


# Vector meson production

- Pomeron dominates at high energies
- Isoscalar exchanges dominantly helicity non-flip ( $\lambda=\lambda'$ )
- Unnatural exchanges only helicity flip ( $|\lambda-\lambda'| = 1$ )

$$\mathcal{M}_{\lambda_V, \lambda_\gamma}^{\lambda', \lambda}(s, t) = \sum_{E=\pi, \eta, \mathbb{P}, f_2, a_2} \mathcal{M}_{\lambda_V, \lambda_\gamma}^E(s, t)$$

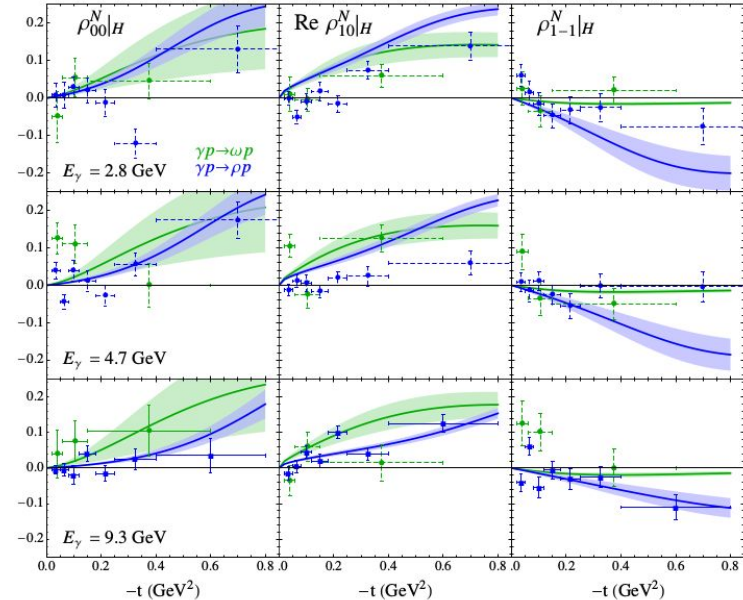
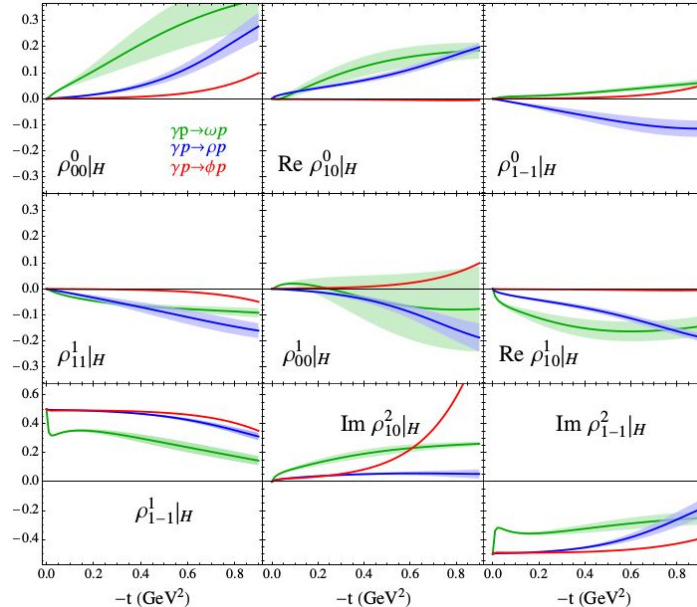
$$\mathcal{M}_{-\lambda_\gamma, -\lambda_V}^N = \pm (-1)^{\lambda_\gamma - \lambda_V} \mathcal{M}_{\lambda_\gamma, \lambda_V}^U$$



# Vector meson production

- Pomeron dominates at high energies
- Isoscalar exchanges dominantly helicity non-flip ( $\lambda=\lambda'$ )
- Unnatural exchanges only helicity flip ( $|\lambda-\lambda'| = 1$ )

$$\mathcal{M}_{\lambda_V, \lambda_\gamma}^{X', \lambda}(s, t) = \sum_{E=\pi, \eta, \mathbb{P}, f_2, a_2} \mathcal{M}_{\lambda_V, \lambda_\gamma}^E(s, t)$$

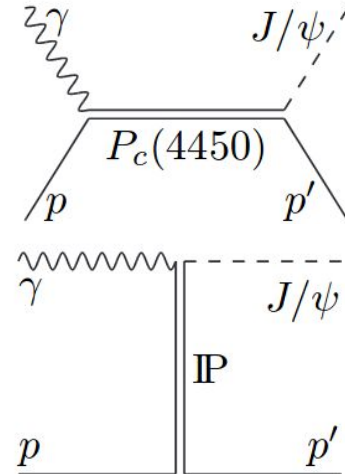


# J/ψ photoproduction

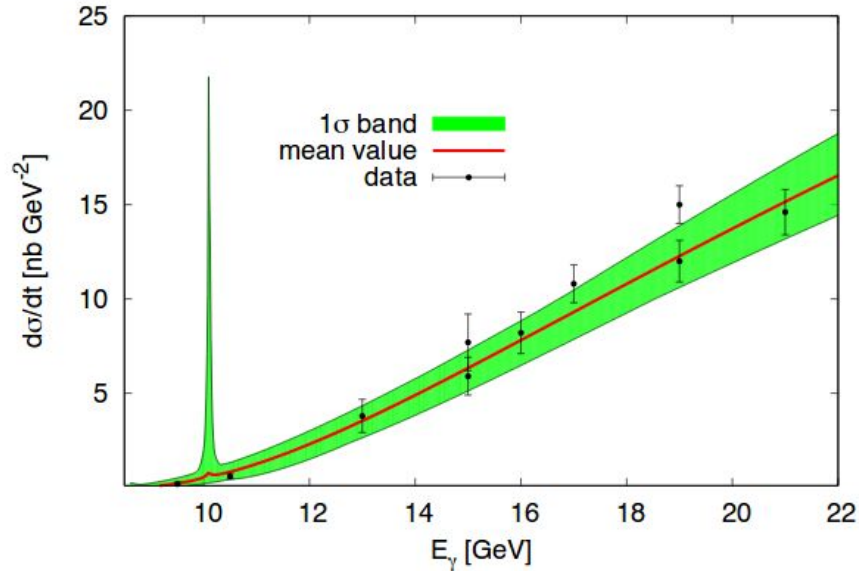
- Propose to search for hidden charm pentaquarks in photoproduction
- Model:
  - Effective Pomeron background
  - Breit-Wigner Pc
- Predictions of cross section (upper limit) assuming VMD

$$\langle \lambda_\psi \lambda_{p'} | T_r | \lambda_\gamma \lambda_p \rangle = \frac{\langle \lambda_\psi \lambda_{p'} | T_{\text{dec}} | \lambda_R \rangle \langle \lambda_R | T_{\text{em}}^\dagger | \lambda_\gamma \lambda_p \rangle}{M_r^2 - W^2 - i\Gamma_r M_r}$$

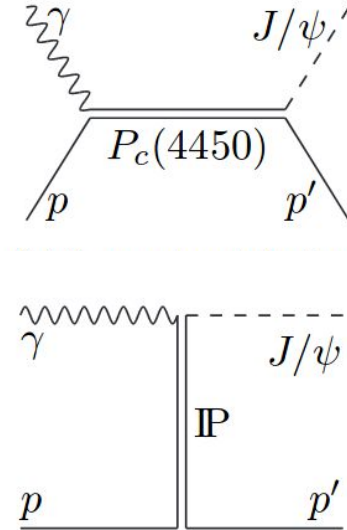
$$\langle \lambda_\psi \lambda_{p'} | T_P | \lambda_\gamma \lambda_p \rangle = iA \left( \frac{s - s_t}{s_0} \right)^{\alpha(t)} e^{b_0(t - t_{\text{min}})} \delta_{\lambda_p \lambda_{p'}} \delta_{\lambda_\psi \lambda_\gamma}$$



# $J/\psi$ photoproduction

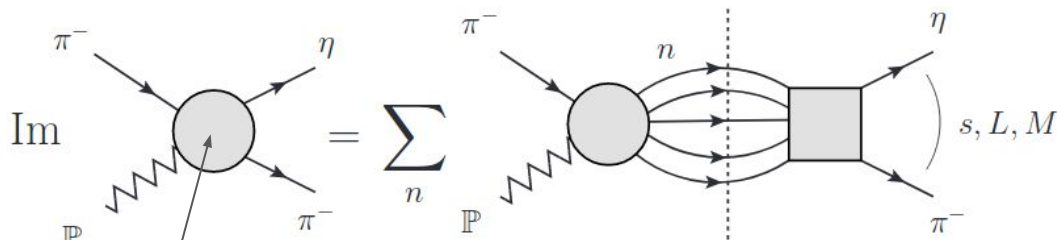
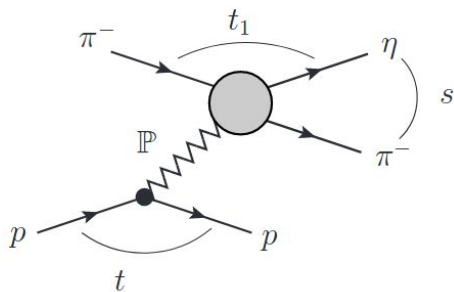


(a)  $J_r = 3/2$ ,  $\sigma_s = 0$  MeV



# Partial-wave analysis: $\eta\pi$

- **Unitarity, analytic** N/D model
- N contains left-hand cuts (exchange forces)
- **D contains right-hand cuts (resonance content)**
- Only **N** changes with the production process (!!!)



$$\hat{a}(s) = \frac{n(s)}{D(s)}$$



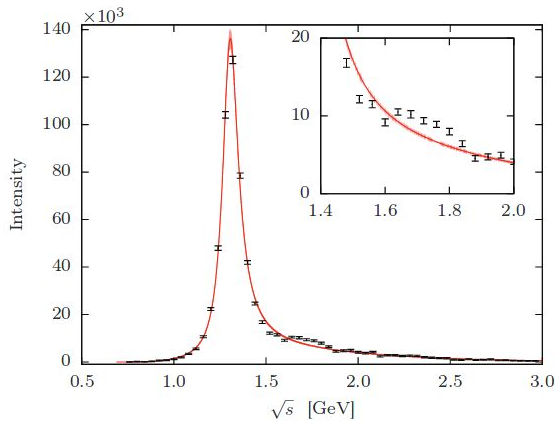
# Partial-wave analysis: $\eta\pi$

$$m(a_2) = (1307 \pm 1 \pm 6) \text{ MeV}$$

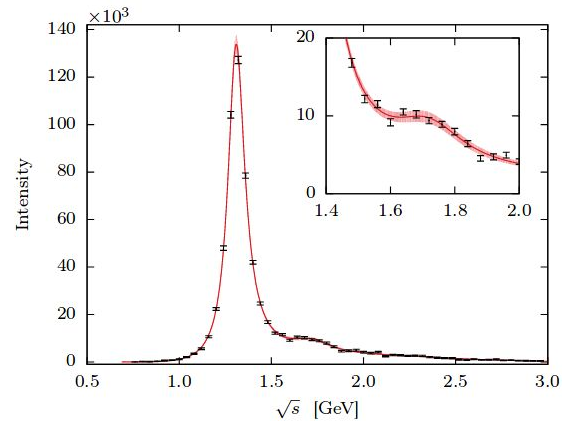
$$\Gamma(a_2) = (112 \pm 1 \pm 8) \text{ MeV}$$

$$m(a'_2) = (1720 \pm 10 \pm 60) \text{ MeV}$$

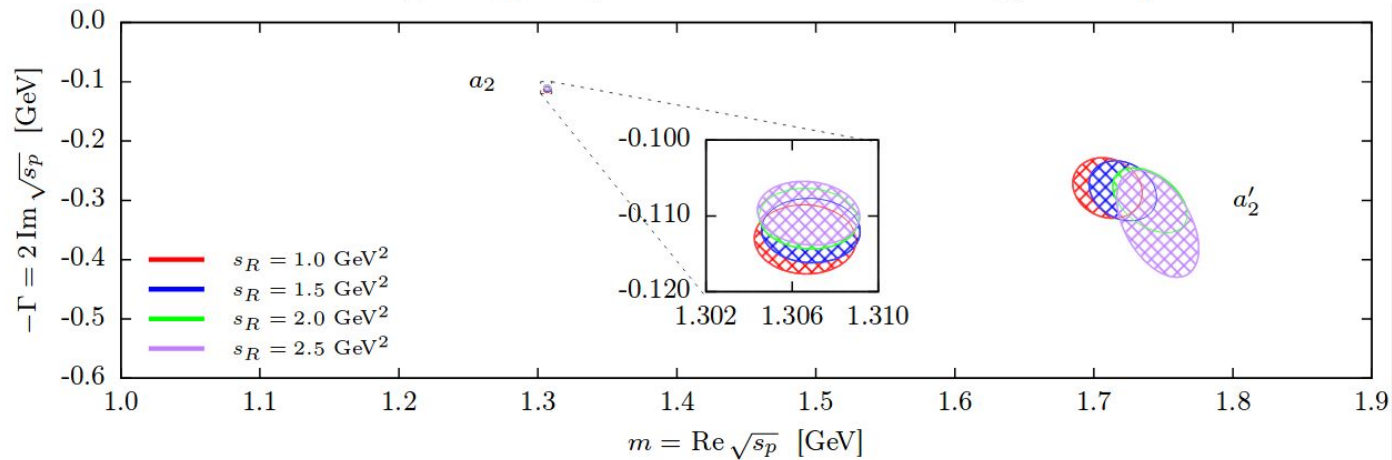
$$\Gamma(a'_2) = (280 \pm 10 \pm 70) \text{ MeV}$$



(a)  $\text{CDD}_\infty$  pole only.



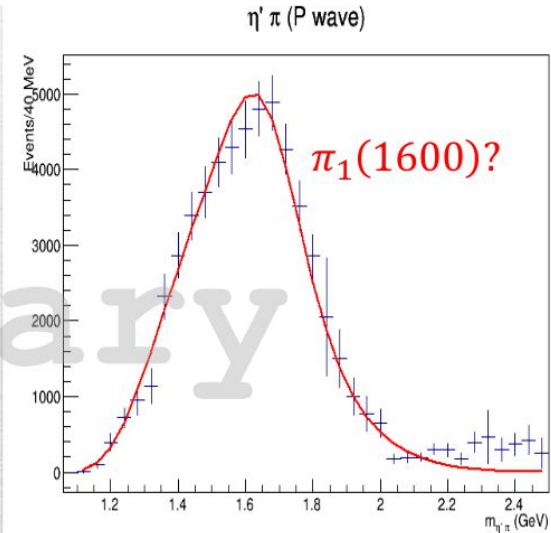
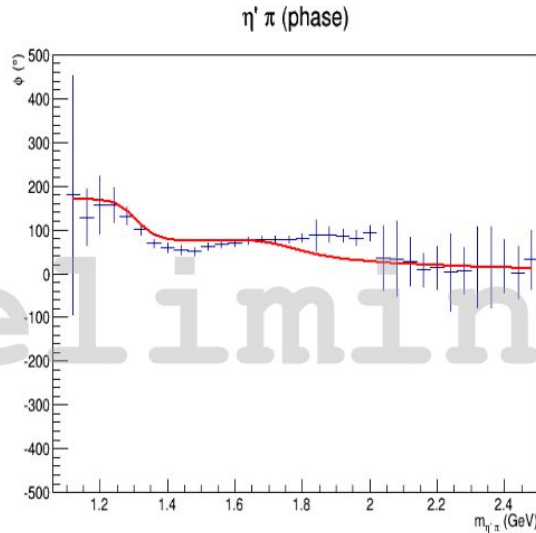
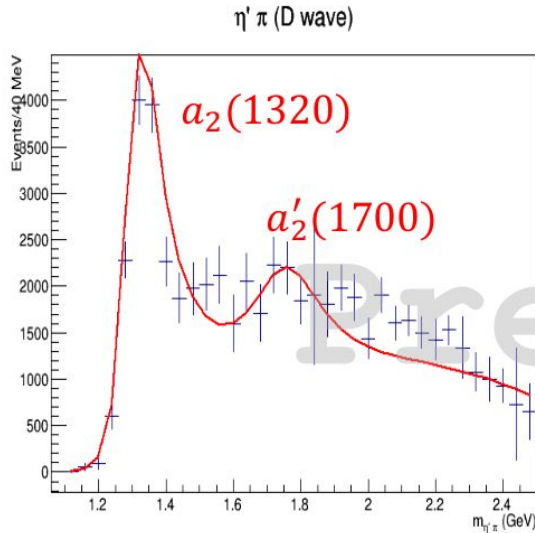
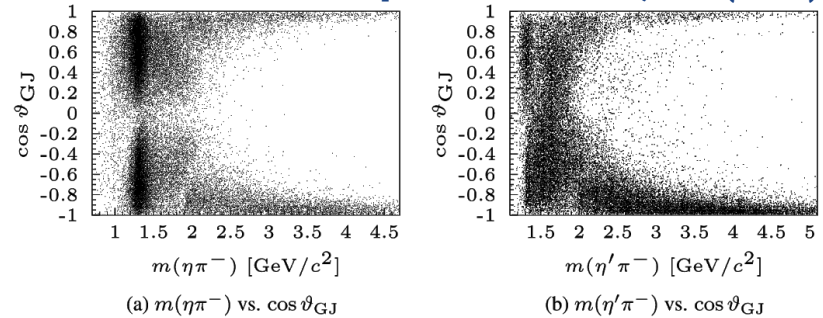
(b) Two CDD poles.



# Partial-wave analysis: $\eta^{(\prime)}\pi$

- Ongoing analysis for
  - Coupled channels:  $\eta\pi$  and  $\eta'\pi$
  - P (exotic) and D waves

[DATA: COMPASS, PLB (2015) 303]



[A.Pilloni et al., in preparation]



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JPAC acknowledges support from DOE and NSF

## NEWS

### Photoproduction:

1. High energy model for  $\pi\Delta$  photoproduction beam asymmetry: (in construction)
2. High energy model for  $\rho^0, \omega, \phi$  spin density matrix elements:  $\gamma p \rightarrow Vp$  page
3. High energy model for  $\eta'$  photoproduction beam asymmetry:  $\gamma p \rightarrow \eta' p$  page
4. High energy model for  $\eta$  photoproduction:  $\gamma p \rightarrow \eta p$  page
5. High energy model for  $\pi^0$  photoproduction:  $\gamma p \rightarrow \pi^0 p$  page
6. High energy model for  $J/\psi$  photoproduction:  $\gamma p \rightarrow J/\psi p$  page

# Summary

- Upper bounds on the unnatural exchange contributions
- Vector meson SDME predictions dominated by natural exchanges
- $J/\psi$  model being extended to produce polarization information
- Analytic and unitary models available for resonance extraction
  - $a_2$  resonances from COMPASS data
  - Exotics are next
  - Model is extendable to JLab production process: *common denominator function D*