JPAC Update

- JPAC Review
- Update on current projects
- New Collaborations
  - LHCb, BESIII, PARTONS project…
- Planned activities:
  - 2017 Gribov Lectures Summer School, FDHS 2017,…

Products

- > 40 Research Papers
- >120 Invited Talks and Seminars
- Several Reaction/Reference Web Pages (include summer school + database)
- ~O(10) Ongoing Analyses
- 1 Summer School on Reaction Theory (IU,2015), 1 Workshop (Future Directions in Hadron Spectroscopy, (JLab, 2014)

Particle Physics on the Cloud

Jefferson Lab > JPAC

Theory Center

JPAC Home | People

LINKS

- Home
- Indiana Univ. JPAC Site
- EBAC (up to 2012)

Joint Physics Analysis Center (JPAC)

The **Joint Physics Analysis Center** (JPAC) was set up in October 2013 between Indiana University (IU) and the Thomas Jefferson National Laboratory (JLab).

Decays

$\eta \to 3\pi$

- **Method:** Amplitudes parametrized with dispersion relations.
- **Status:** Published in [Guo15a]
- **Material:** Available on the $\eta \to 3\pi$ page
- **Contact person:** Peng Guo

$\omega,\phi \to 3\pi$, $\pi\gamma^*$

- **Method:** Amplitudes parametrized with dispersion relations.
- **Status:** Published in [Dan14a]
- **Material:** Available on the $\omega,\phi \to 3\pi$ page
- **Contact person:** Igor Danilkin

$J/\psi,\psi' \to 3\pi$

- **Method:** Amplitudes parametrized with the Veneziano dual model.
- **Status:** Published in [Szc14a] .
- **Material:** Available upon request.
- **Contact person:** Adam Szczepaniak

Single Meson Production

$\pi N \to \pi N$

Method: Finite energy sum rules between resonance and Regge regions.
Status: Finished.
Material: Available upon request.
Contact person: Vincent Mathieu

$K N \to K N$

Method: Finite energy sum rules between resonance and Regge regions.
Status: Under development.
Material: Under development.
Contact person: Cesar Fernández-Ramírez

$\gamma N \to \pi^0 N$

Method: Amplitudes parametrized with Regge poles.
Status: Published in [Mat15a] .
Material: Available on the $\gamma p \to \pi^0 p$ page
Contact person: Vincent Mathieu

Double Meson Production

$\gamma N \to K^+ K^- N$

Method: Amplitudes in the double Regge region parametrized with dual B_5 model.
Status: Published in [Shi14a]
Material: Available upon request.
Contact person: Meng Shi

$\pi N \to \pi\eta N$

Method: Finite energy sum rules between resonance and Regge regions.
Status: Under development.
Material: Under development.
Contact person: Vincent Mathieu

ort News, VA 23606
57) 269-7002

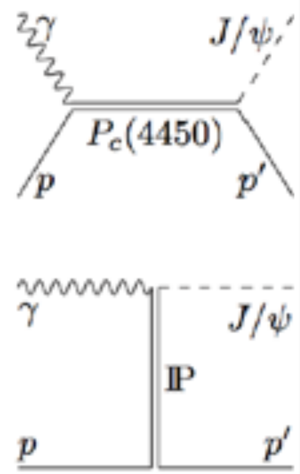
contact Ron Workman

National Science Foundation

This project is supported by NSF

$\gamma p \to J/\psi p$

This section follows closely our publication in Ref. [Blin16a] .
See this publication for more detailed information and references.



Formalism

The two processes contributing to $\gamma p \to J/\psi p$ are shown in the figure. The top diagram represents the direct production of the $P_c(4450)$ resonance. The bottom diagram represent the background. The nonresonant background is expected to be dominated by the t-channel Pomeron exchange, and we saturate the s-channel by the $P_c(4450)$ resonance. In the following we consider only the most favored $J_r^P = 3/2^-$ and $5/2^+$ spin-parity assignments for the resonance. We adopt the usual normalization conventions, and express the differential cross section in terms of the helicity amplitudes $\langle \lambda_\psi \lambda_{p'} | T_r | \lambda_\gamma \lambda_p \rangle$.

$$\frac{d\sigma}{d\cos\theta} = \frac{4\pi\alpha}{32\pi s}\frac{p_f}{p_i}\frac{1}{4}\sum_{\lambda_\gamma,\lambda_p,\lambda_\psi,\lambda_{p'}} |\langle \lambda_\psi \lambda_{p'} | T | \lambda_\gamma \lambda_p \rangle|^2. \quad \text{(A}$$

Here, p_i and p_f are the incoming and outgoing center-of-mass frame momenta, respectively, θ is the center-of-mass scatteri angle, and $W = \sqrt{s}$ is the total energy in the center-of-mass . Note that the electric charge $\sqrt{4\pi\alpha}$ is explicitly factored out fr the matrix element. The contribution of the $P_c(4450)$ resonance is parametrized using the Breit-Wigner ansatz,

$$\langle \lambda_\psi \lambda_{p'} | T_r | \lambda_\gamma \lambda_p \rangle = \frac{\langle \lambda_\psi \lambda_{p'} | T_{\text{dec}} | \lambda_r \rangle \langle \lambda_r | T^\dagger_{\text{em}} | \lambda_\gamma \lambda_p \rangle}{M_r^2 - W^2 - i\Gamma_r M_r}. \quad \text{(A}$$

The numerator is given by the product of photo-excitation and hadronic decay helicity amplitudes. The measured width is narrow enough to be approximated by a constant, $\Gamma_r = (39 \pm 24)$ MeV. The angular momentum conservation restricts the sum over λ_r, the spin projection along the beam direction in the center of mass frame, to $\lambda_r = \lambda_\gamma - \lambda_p$. The hadronic helicity amplitude T_{dec}, which represents the decay of the resonance of spin J to the J/ψ state, is given by

$$\langle \lambda_\psi \lambda_{p'} | T_{\text{dec}} | \lambda_r \rangle = g_{\lambda_\psi \lambda_{p'}} d^J_{\lambda_r, \lambda_\psi - \lambda_{p'}}(\cos\theta), \quad \text{(A.3)}$$

where $g_{\lambda_\psi \lambda_{p'}}$ are the helicity couplings between the resonance and the final state. There are three independent couplings ($\lambda_{p'} = \frac{1}{2}$, $\lambda_\psi = \pm 1, 0$), the other three being related by parity. For simplicity, we assume all these couplings to be equal, i.e. $g_{\lambda_\psi \lambda'_p} = g$. The helicity amplitudes and the partial decay width $\Gamma_{\psi p}$ are related by

Kinematics:

Beam energy smearing in MeV: 0.0

Parameters of the background (Pomeron exchange):

A (dimensionless) 0.156 s_t in GeV^2 16.8 b_0 in GeV^{-2} 1.01
α_0 (dimensionless) 1.151 α' in GeV^{-2} 0.112

Parameters of the direct production:

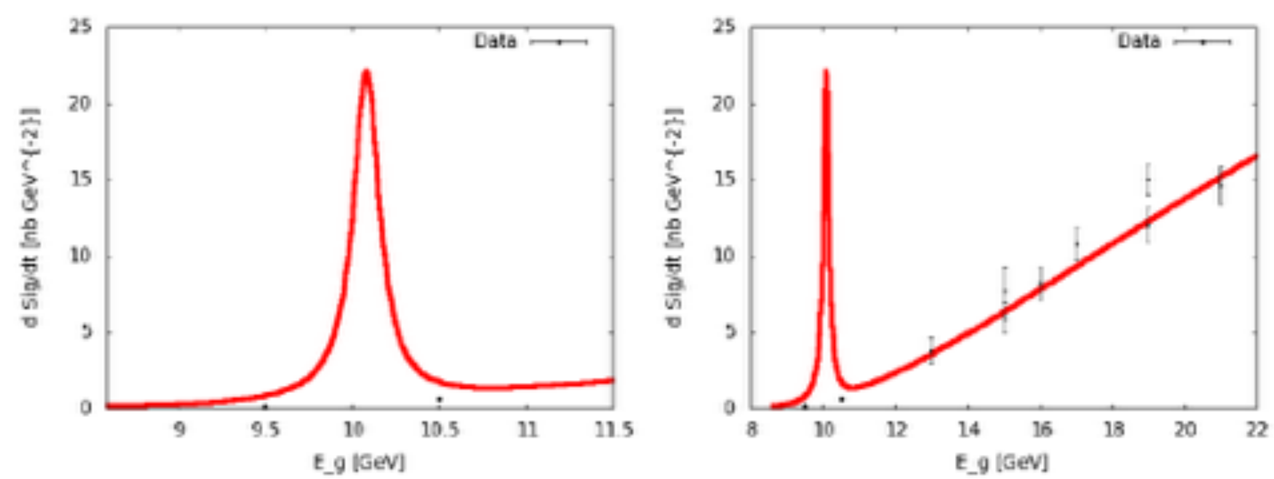
Spin of the $P_c(4450)$: $3/2^-$ $5/2^+$
Photocoupling ratio: $r_{1/2}$ 0.71
$\mathcal{B}_{\psi p}$ (dimensionless) 0.29 M_r in GeV 4.45 Γ_r in GeV 0.039

Observable:

$\frac{d\sigma}{dE_\gamma}(t'=0)$ $\sigma_{\text{tot}}(E_\gamma)$ $\frac{d\sigma}{dt}(s = M_r^2)$
$E_{\max}$ for $\frac{d\sigma}{dE_\gamma}(t'=0)$ 22.0
Start reset

Results

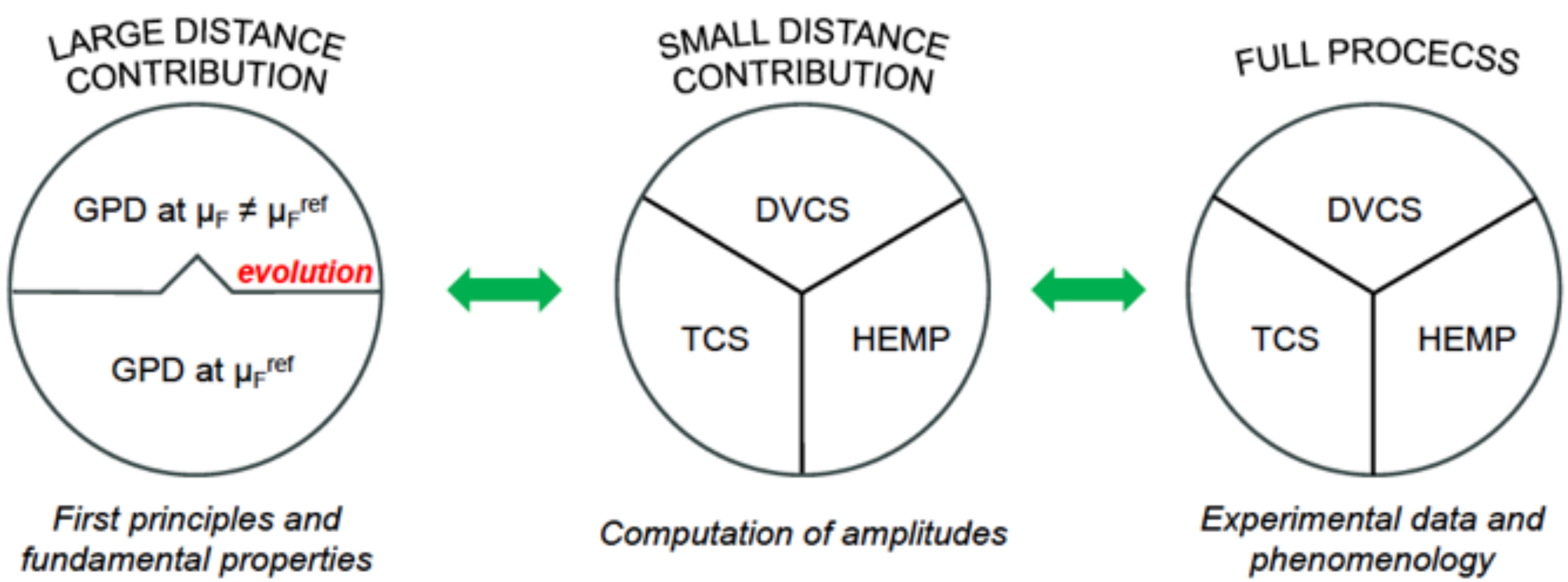
Simulations parameters:
Pomeron: A = 0.156 ; st = 16.8 GeV^2 ; b0 = 1.01 GeV^{-2}; alpha0 = 1.151 ; alpha' = 0.112 GeV^{-2}
Pentaquark: spin = 3/2 ; BR = 0.29 ; Mr = 4.45 GeV ; Gr = 0.039 GeV ; r1/2 = 0.71 ;
Smearing = 0.0 MeV
The observable is the differential cross section in the forward direction up to Emax = 22.0 GeV.



Download the output file and the plot

PARTONS (PARtonic Tomography Of Nucleon Software)

B. Berthou (Irfu), D. Binosi(ECT*), N. Chouika (Irfu), L. Colaneri (IPNO/U.Conn.), M. Guidal (IPNO), K. Joo (U. Conn), P. Lafitte (ECP), C. Mezrag (Argonne), H. Moutarde (Irfu), F. Sabatie (Irfu), P. Sznajder (IPNO), P. Rodríguez Quintero (UHU), J. Wagner (NCBJ Warsaw)



Tasks and challenges:

- Physical models
- Perturbative approximations
- Many observables
- Numerical methods
- Accuracy and speed
- Fits

JPAC Review (May 3-4/2016)

- Committee members:
  Abhay Deshpande, Curtis Meyer, Stephan Paul, Jonathan Rosner, Stephen Sharpe & Eric Swanson

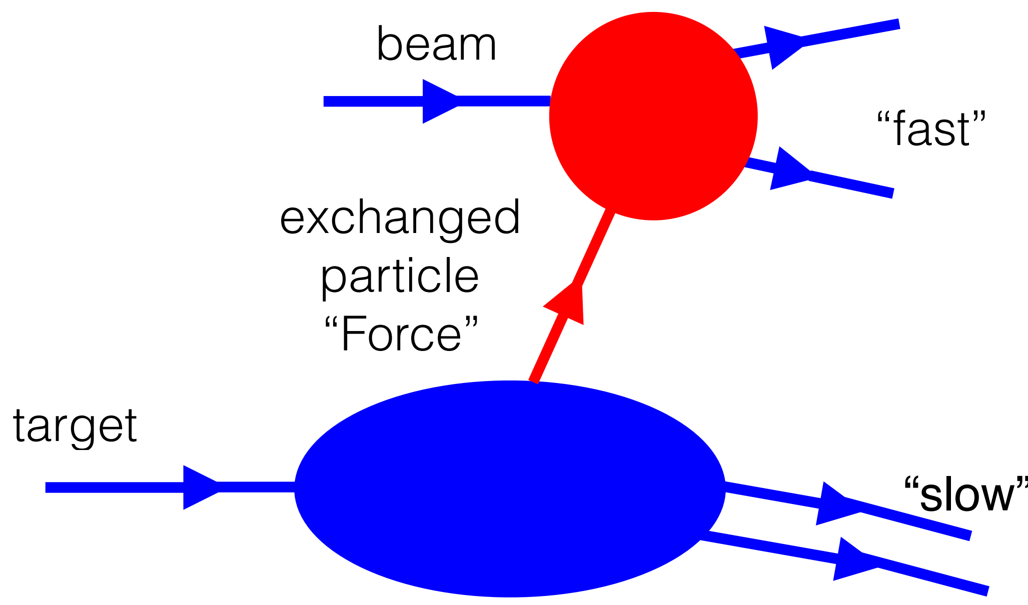
- Charge:
  "… solicit your opinion on the scope and quality of the work performed under the JPAC umbrella, its relevance and importance to the JLab physics program, as well as to the wider hadron community, and your advice on research directions for the future."

- Report:
  Very positive, recommend continuing funding/support

Future analyses for hadron spectroscopy

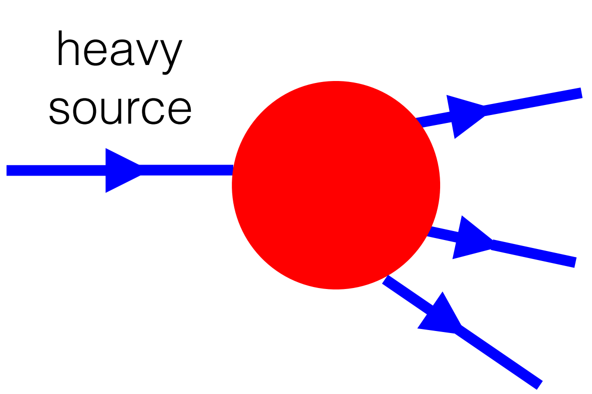
- Complete development of 2-to-2 reactions, establish factorization (and corrections to) of beam-target fragmentation

  (CLAS12, GLueX, COMPASS)



- 3 (and more) particle decays of heavy sources

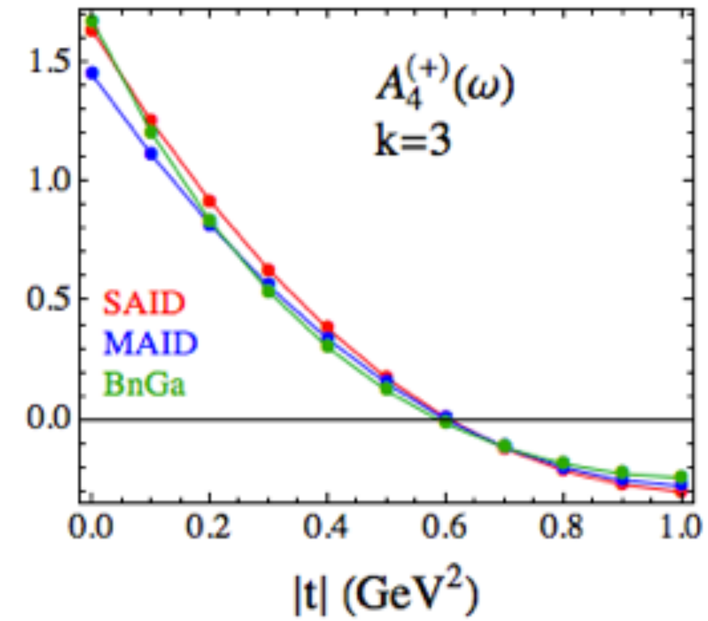
  (BESIII, Babar, LHCb)

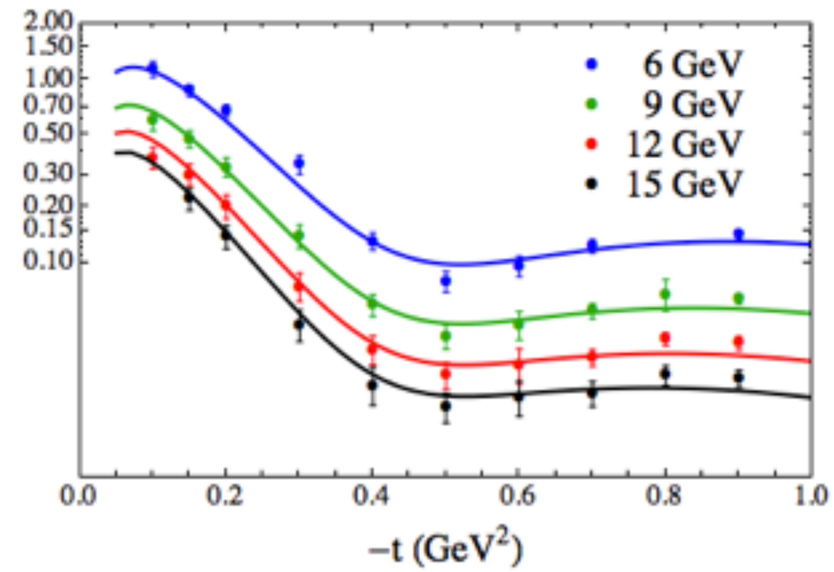


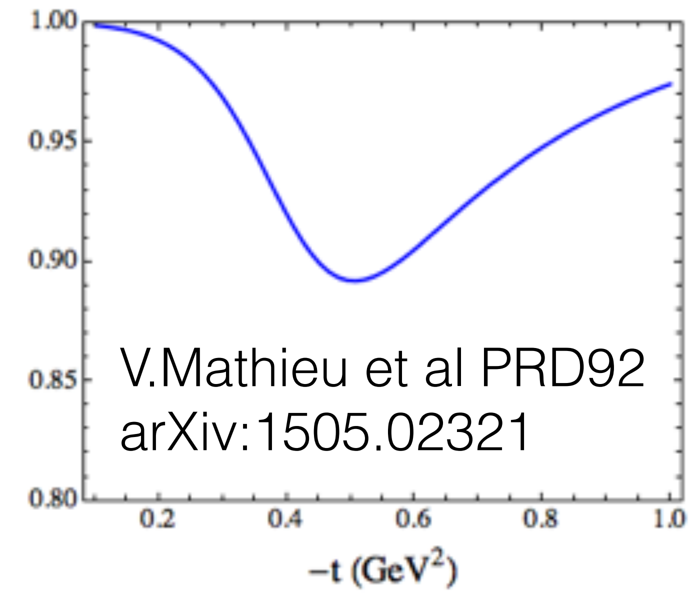
Omega nucleon non-flip $A_4^{\pi^0}(\omega)$ dominates neutral pion photoproduction

$A_4^{\pi^0}(\omega)$ **has a zero** → **dips in $\frac{d\sigma}{dt}$ and Σ**

V.Mathieu et al (JPAC) in preparation

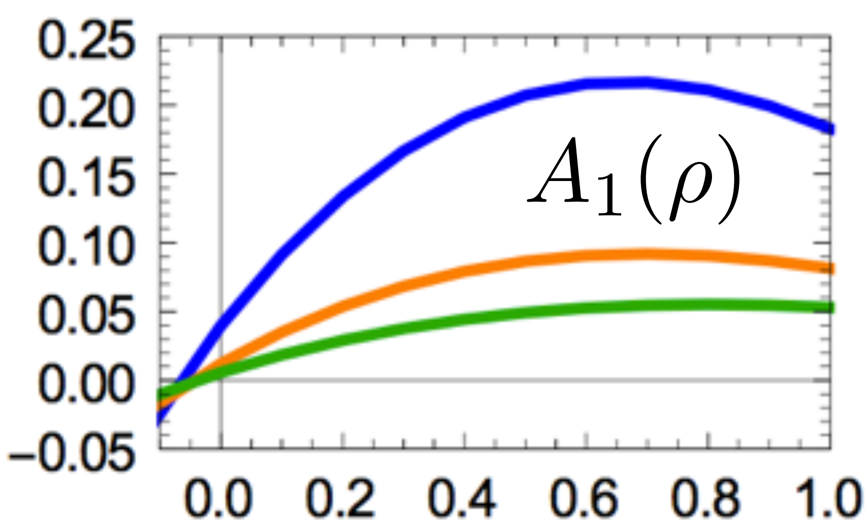


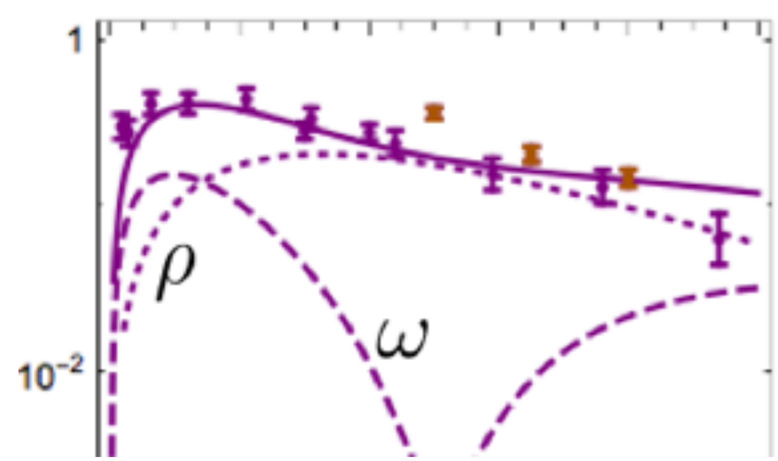


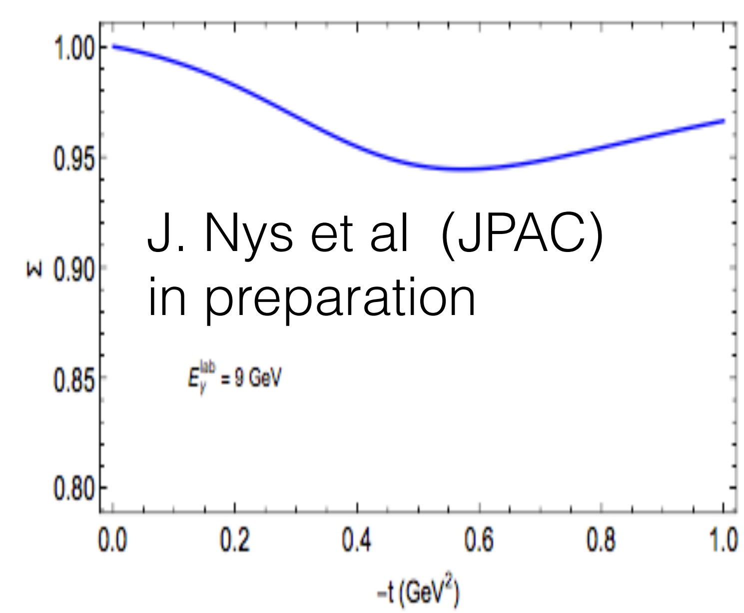


Omega and Rho nucleon non-flip cancel in eta photoproduction
Rho nucleon flip dominate

$A_1^{\eta}(\rho)$ **finite** → **no dip in $\frac{d\sigma}{dt}$ and small dip in Σ**

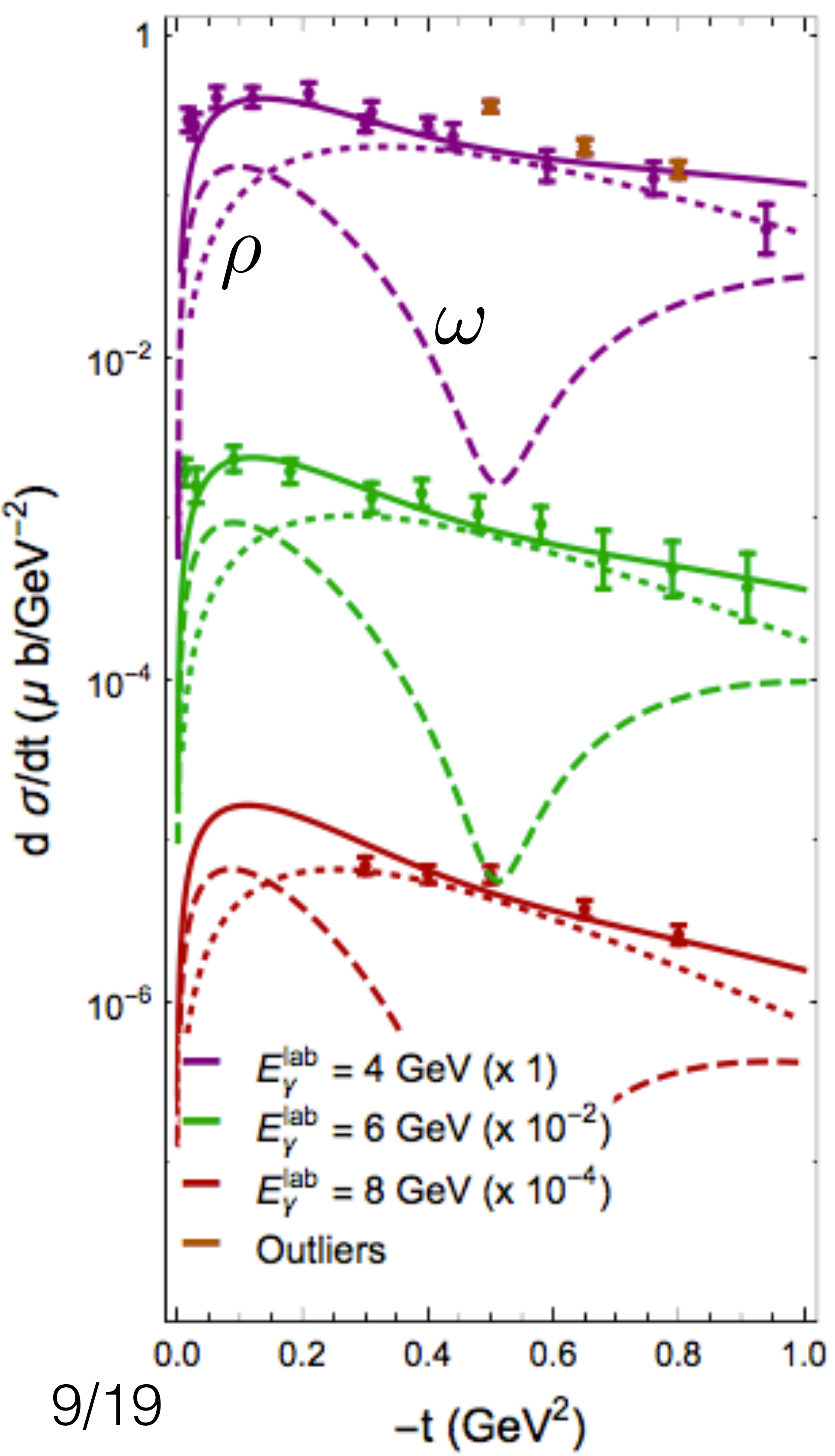


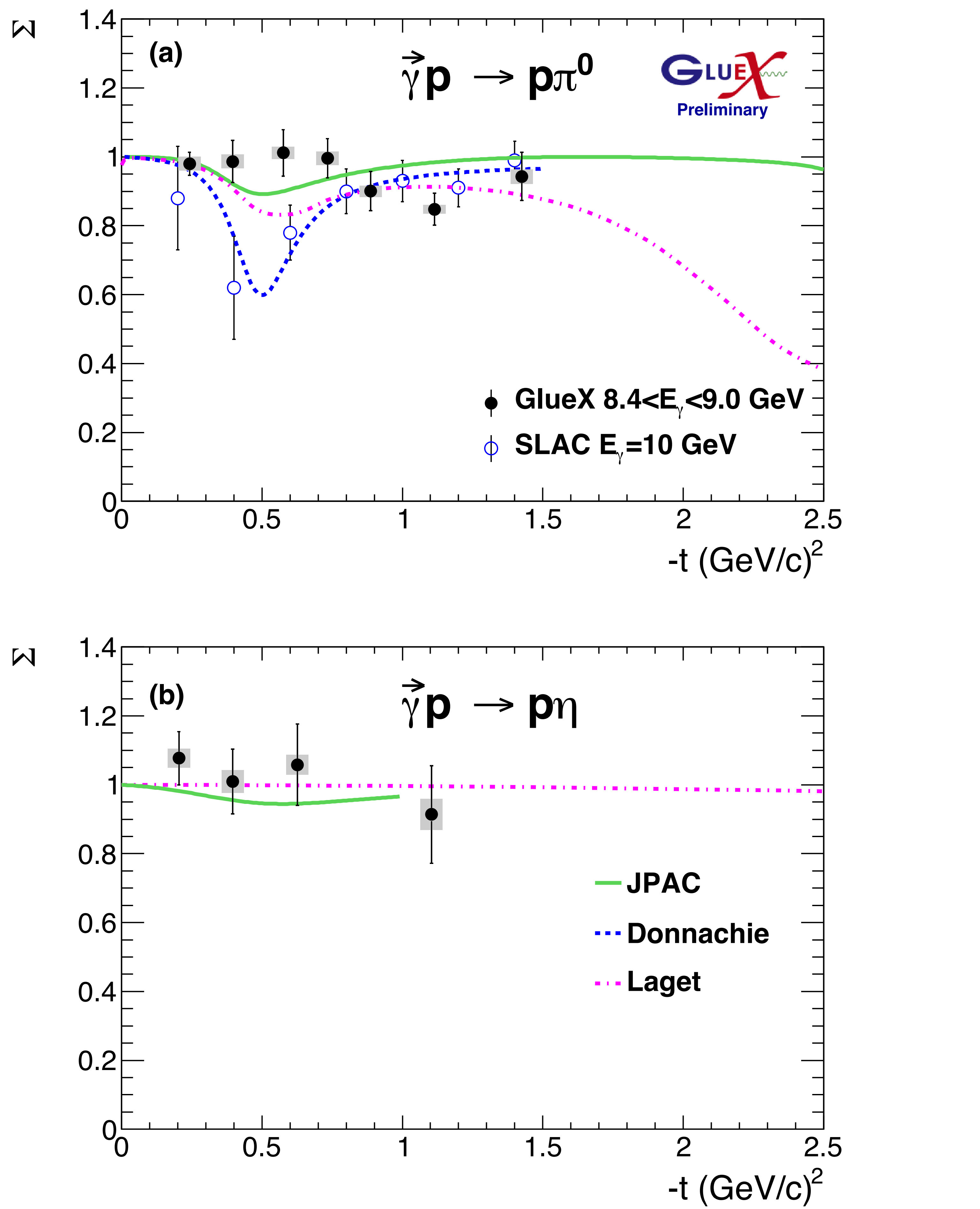




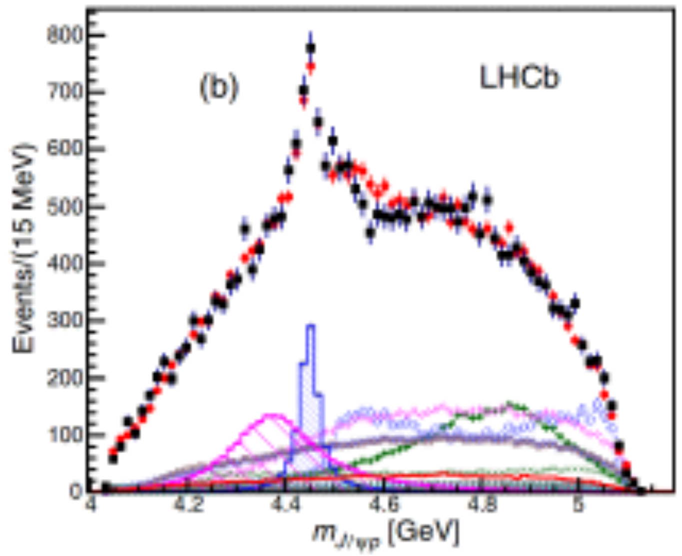
GlueX collaboration, in preparation
M. Shepherd talk @DNP2016 Vancouver

$$\gamma p \rightarrow \eta p$$





$P_c(4450)$ in J/ψ photo production



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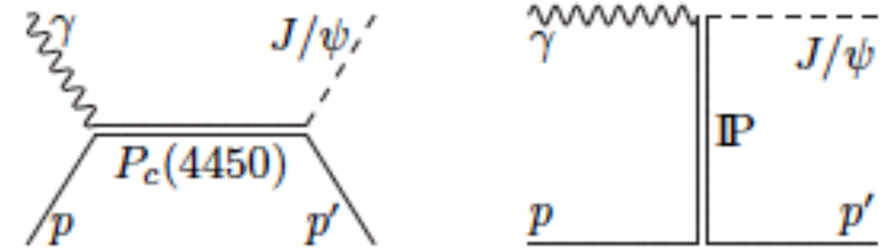


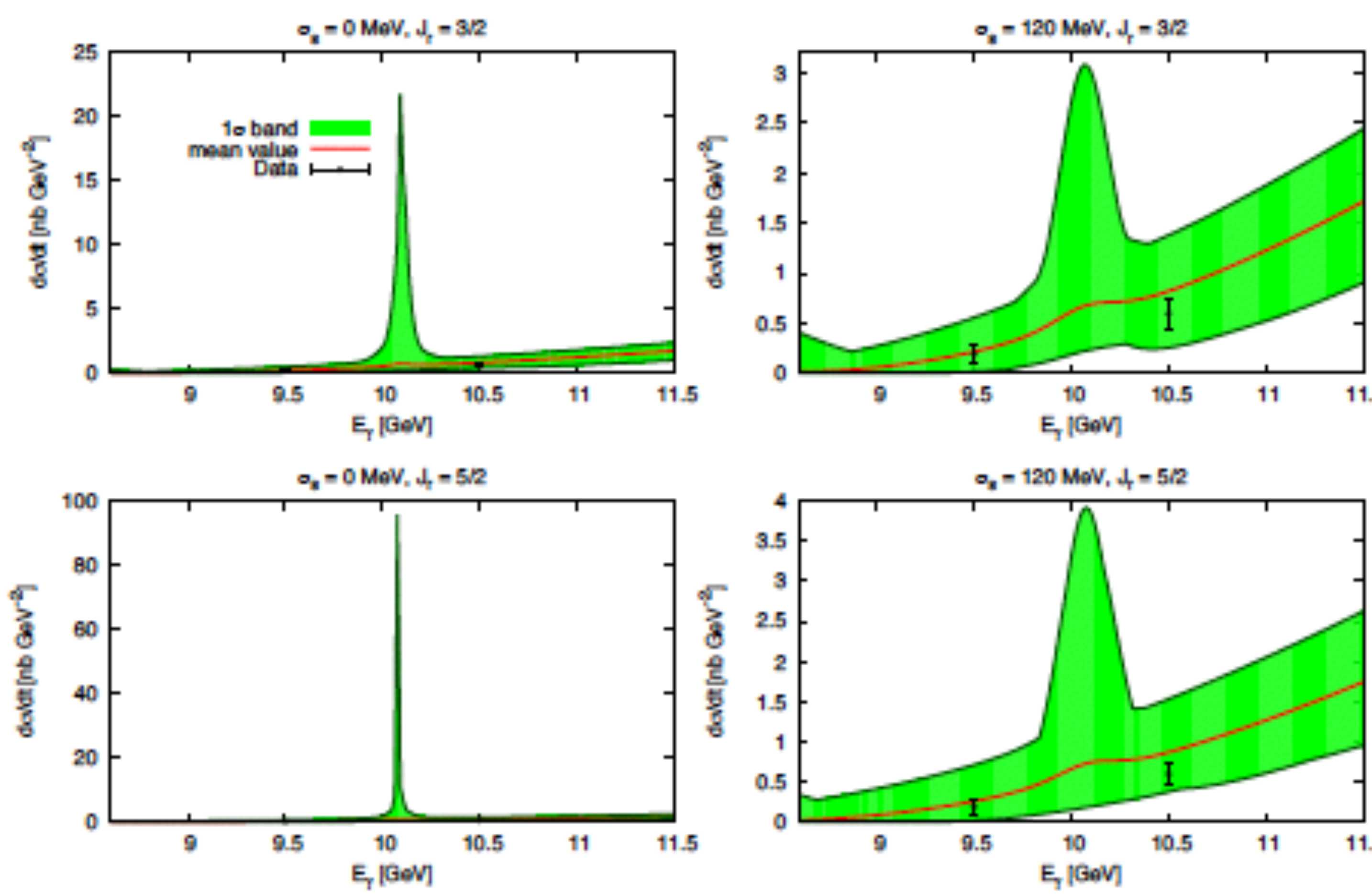
LHCb Collaboration, PRL 115, 072001 (2015)

Fit to data! W from threshold to ~ 300 GeV.

Upper bound for partial decay width!

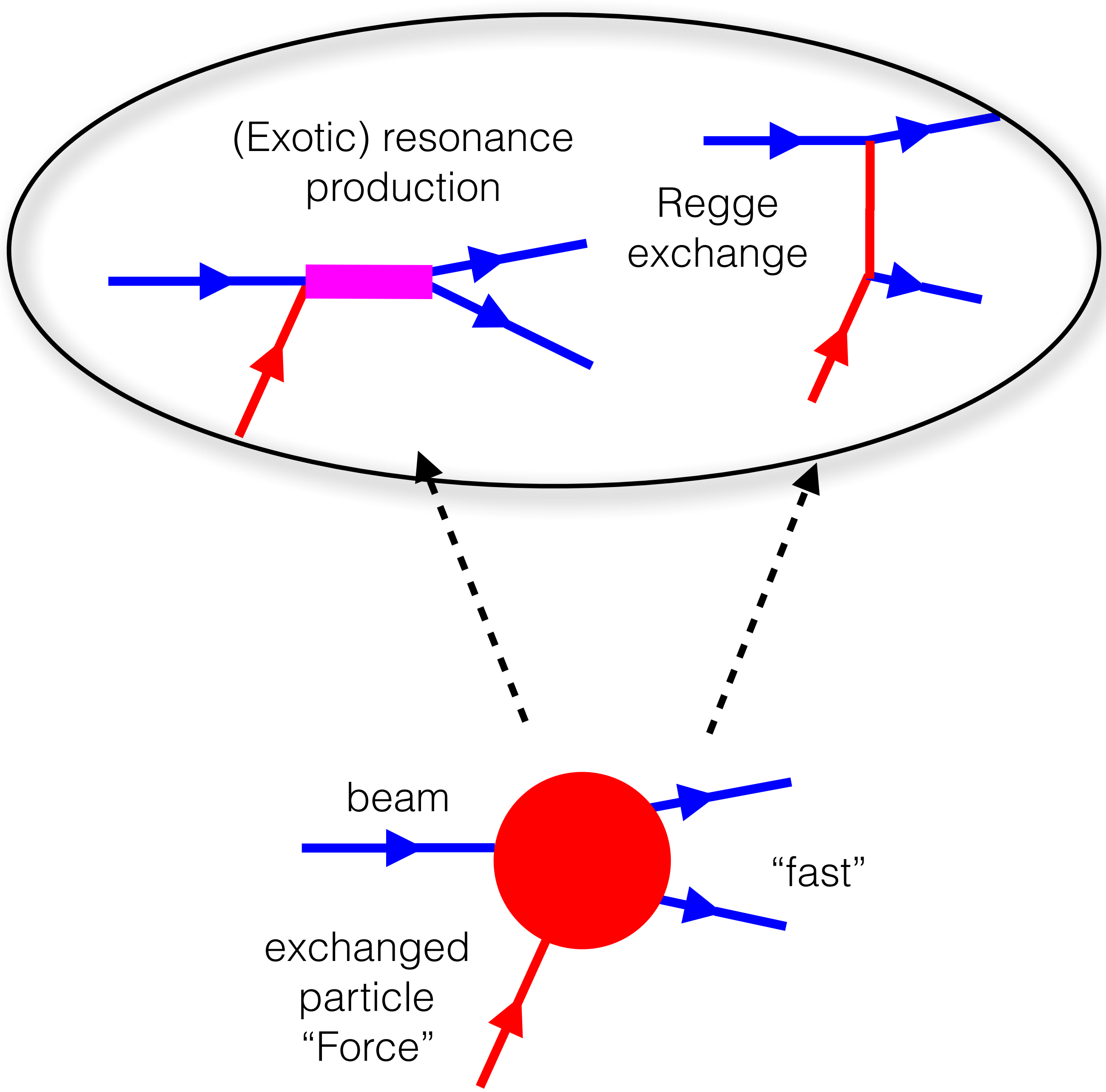
$$\begin{cases} J_r = 3/2 \Rightarrow 23 - 30\% \\ J_r = 5/2 \Rightarrow 8 - 17\% \end{cases}$$

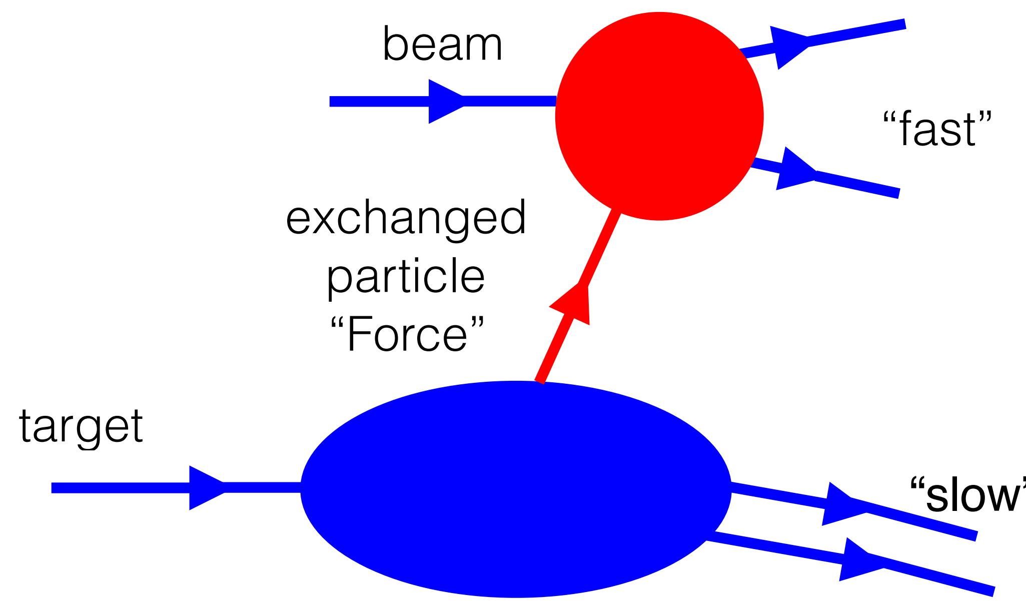
Also angular distributions and photocouplings studied.

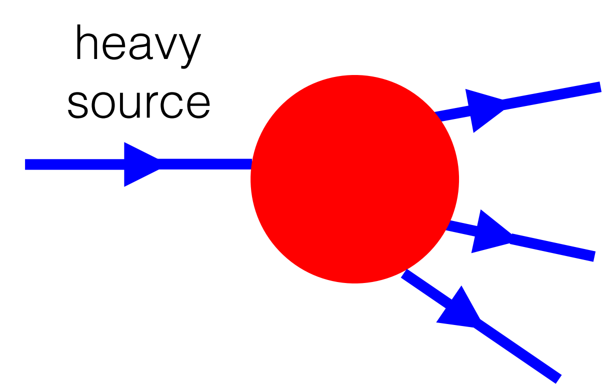


Astrd Blin, et al. (JPAC), Phys.Rev. D94 (2016), 034002

Resonances vs Backgrounds

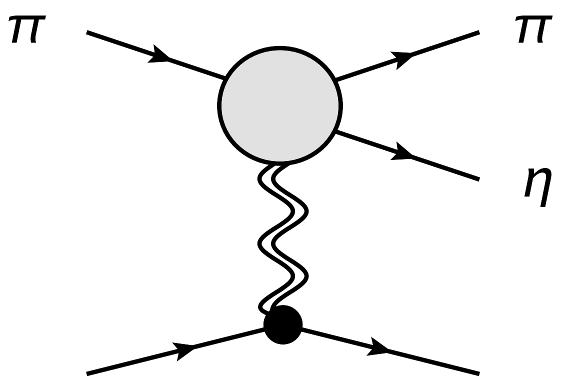


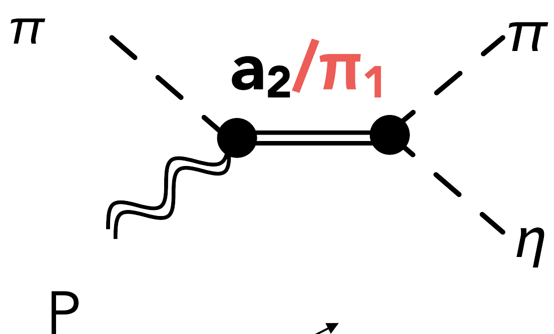


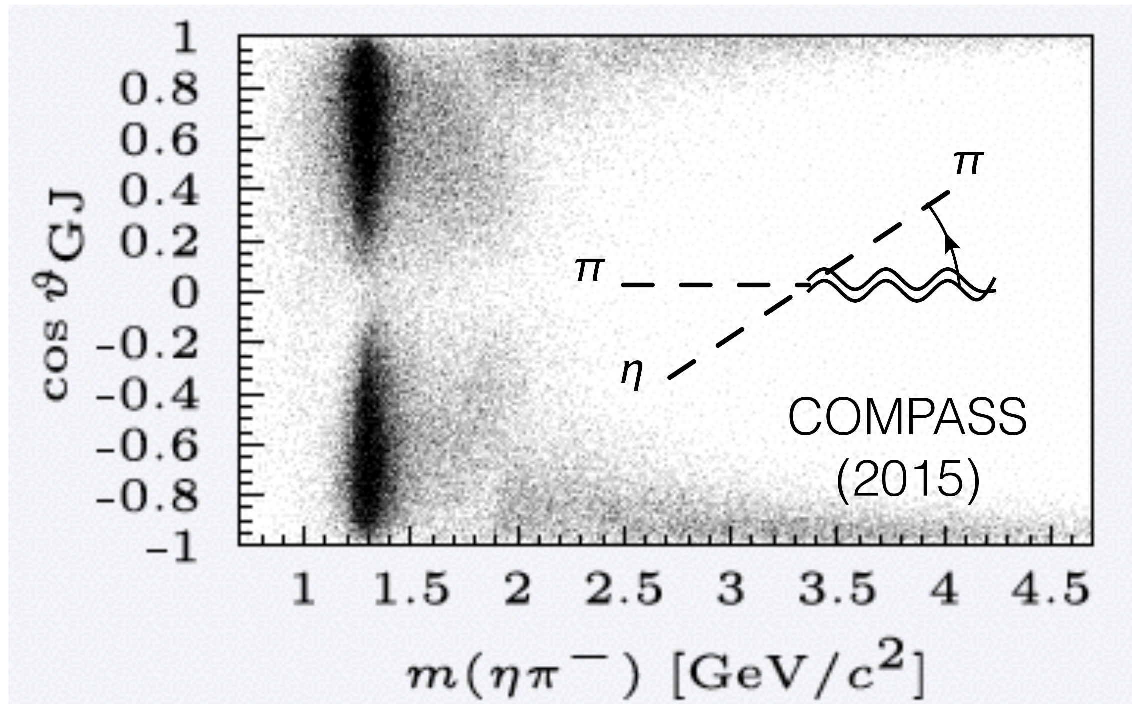


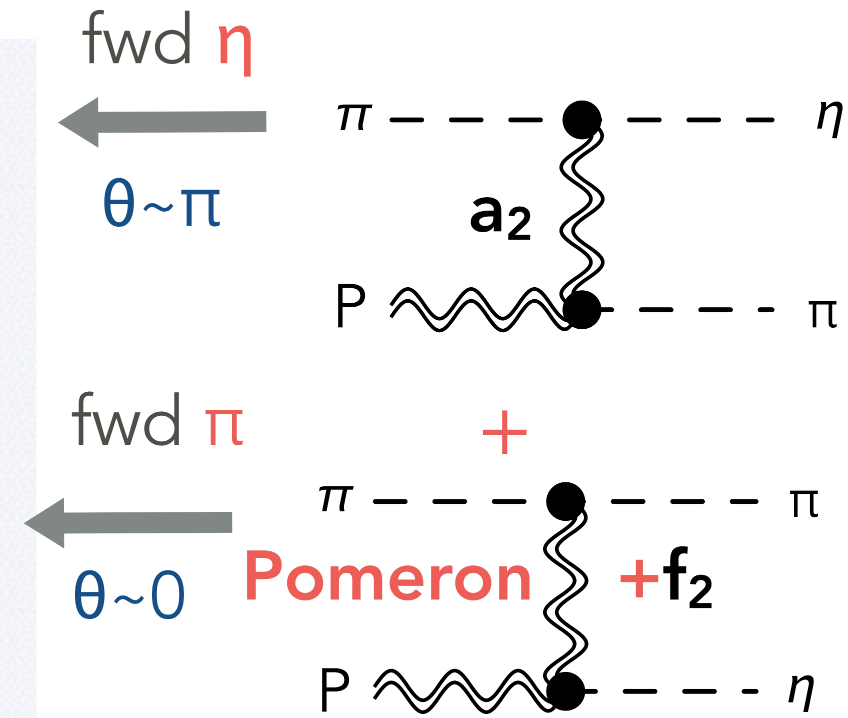
Finite Energy Sum Rules (FESR's) first time to be applied in analysis of 2-to-3 reactions!

forward-backward asymmetry due to P wave !

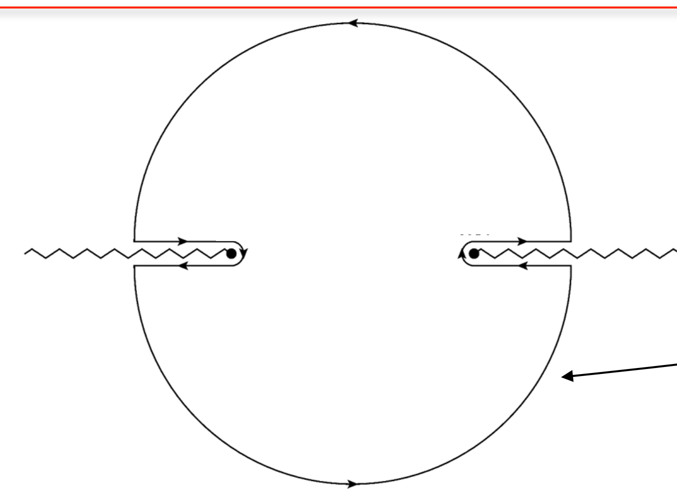








Magnitude of the P wave (exotic resonance) at low η π mass is related by FESR to Regge exchanges at high η π invariant mass

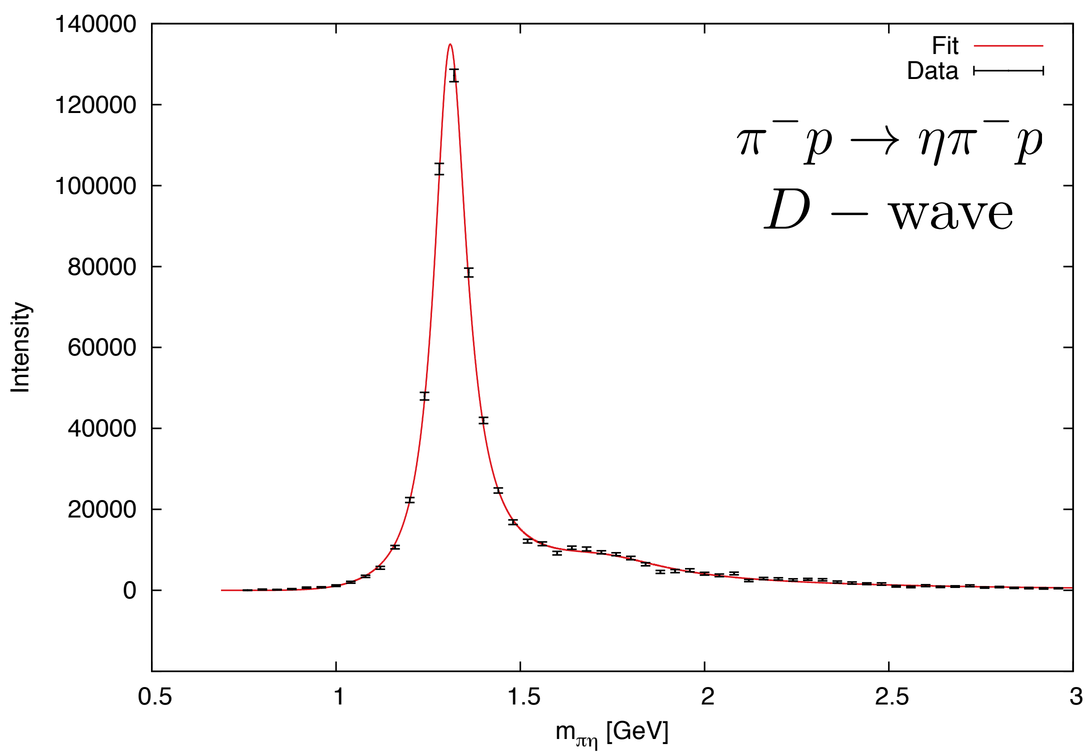


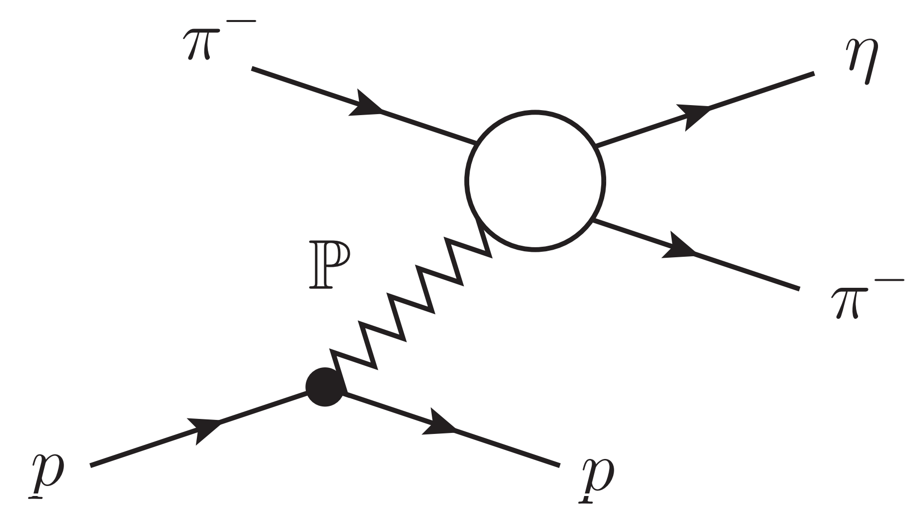
V.Pauk, in preparation

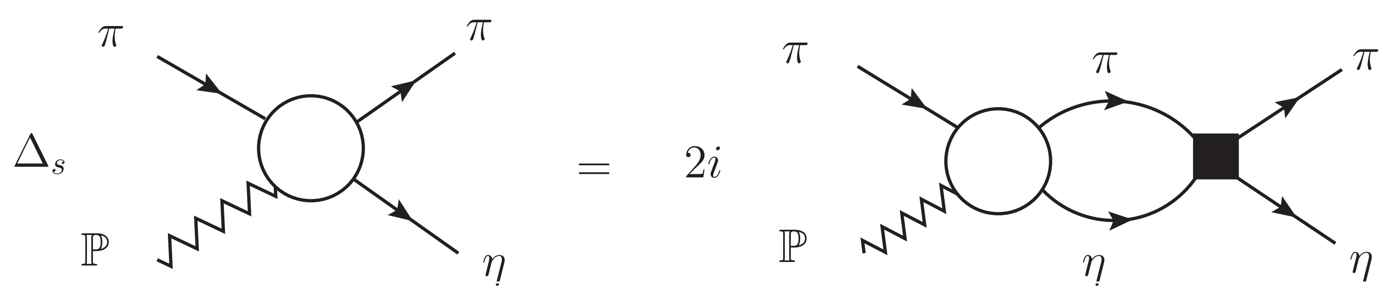
$$\int^{\Lambda} Im A_i(s_1, t_1, t_2) = \int_{\Lambda} Im A_i(s_1, t_1, t_2)$$

$\eta\pi$ Production

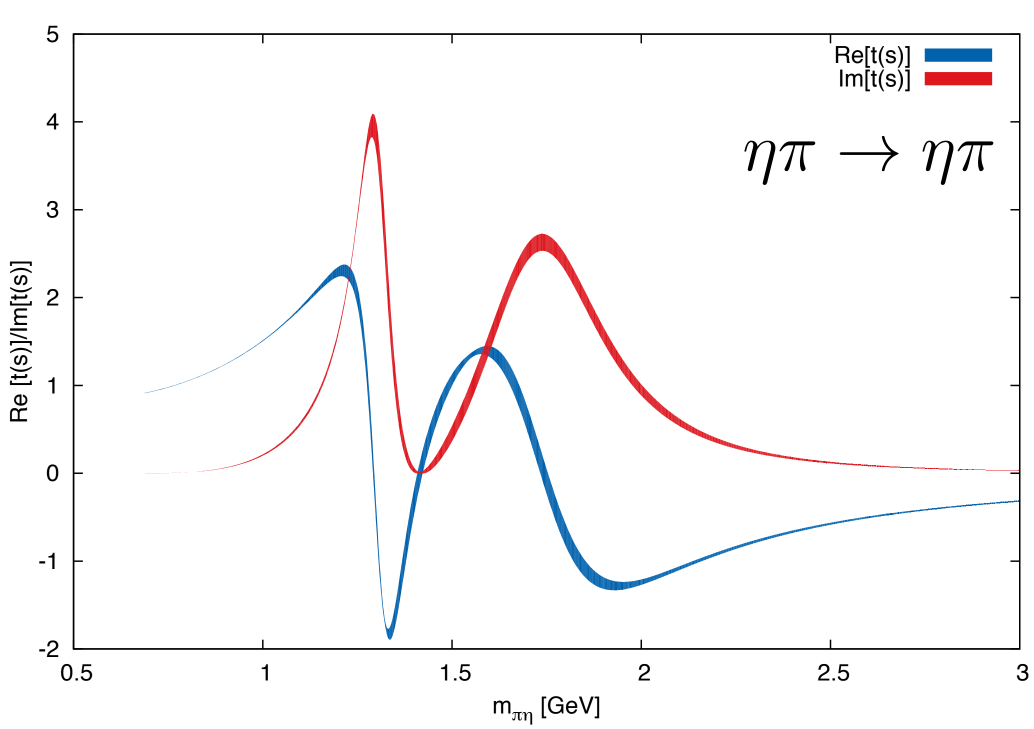
$$I^{JM}(s) = \rho(s)|a^{JM}(s, t_{avg})|^2$$

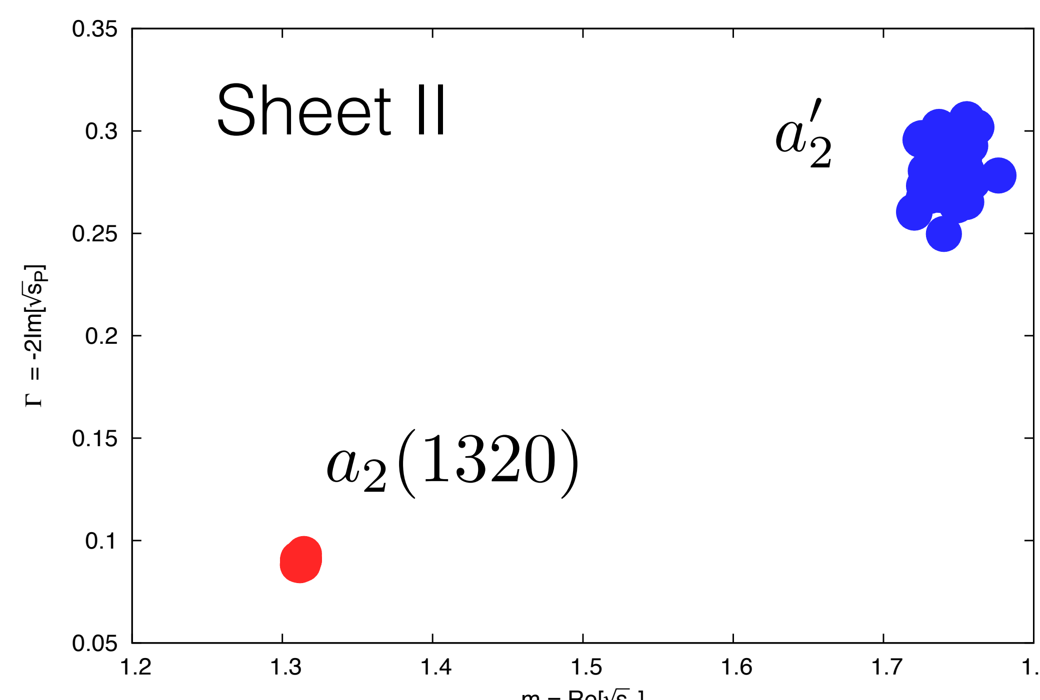






$$\mathrm{Im}\, a^{JM}(s) = \rho(s)\, t^{J\,*}(s)\, a^{JM}(s)$$

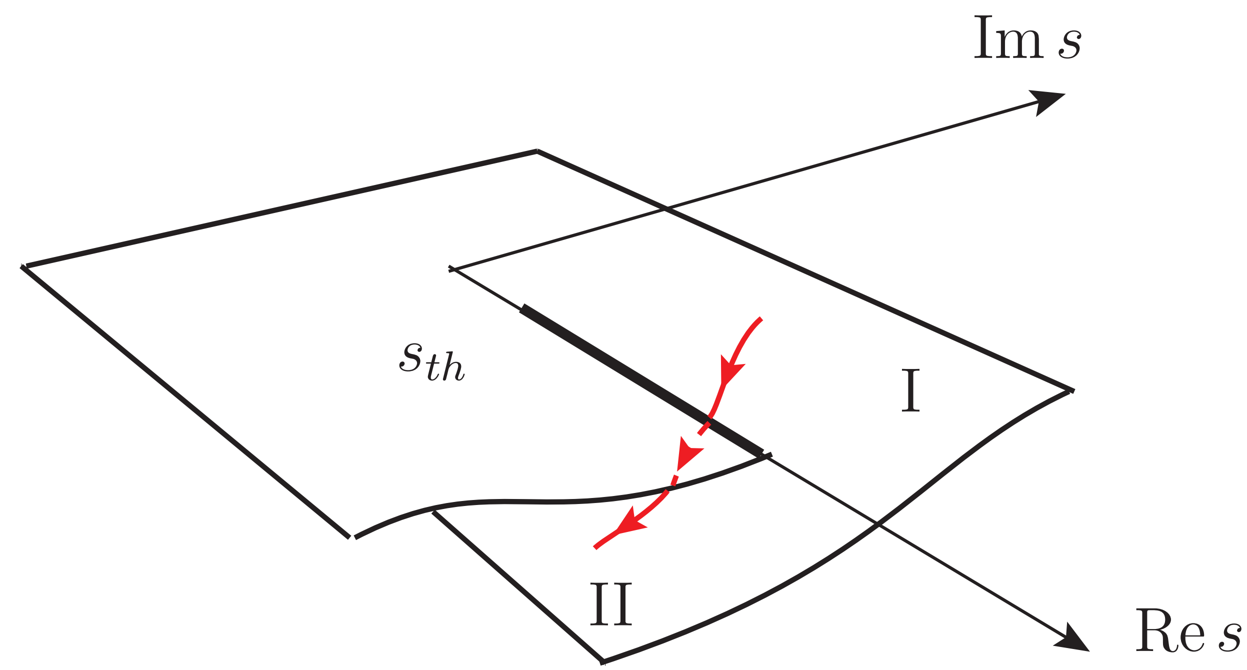




A.Jakura, C.F.Ramirez in preparation

Pole Extraction - K-matrix vs. CDD poles

- Need reliable parameterizations to extract resonance parameters
- Models must satisfy unitarity conditions
- In addition, resonance pole positions must be on unphysical sheets



$$\mathrm{Im}\, t(s) = \rho(s)|t(s)|^2 \implies t^{-1}(s) = K^{-1}(s) - \frac{s}{\pi}\int_{s_{th}}^{\infty} ds' \, \frac{\rho(s')}{s'(s'-s)}$$

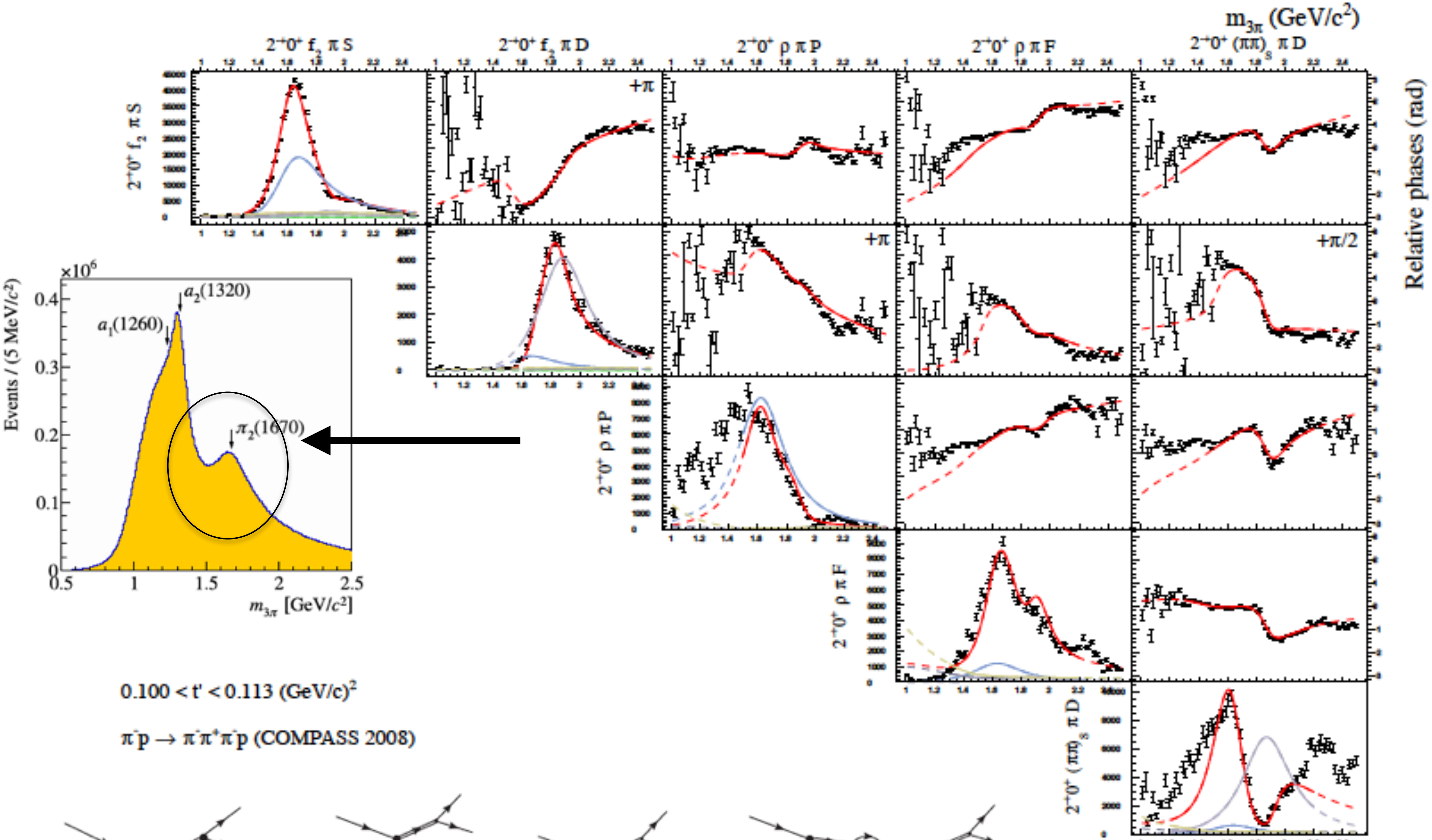
$$K(s) = \sum_r \frac{g_r^2}{m_r^2 - s} + \sum_j \gamma_j \, s^j$$

No obvious constraints on parameters

$$K^{-1}(s) = C_0 - C_1 s - \sum_{r=1}^{N} \frac{C_2^r}{C_3^r - s}$$

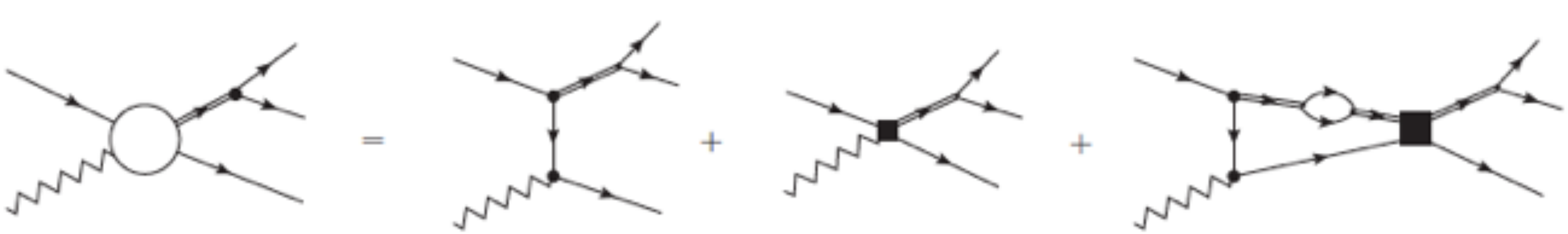
If $C_1, C_2 > 0$, then NO poles on first sheet!

Fit over all t' slices



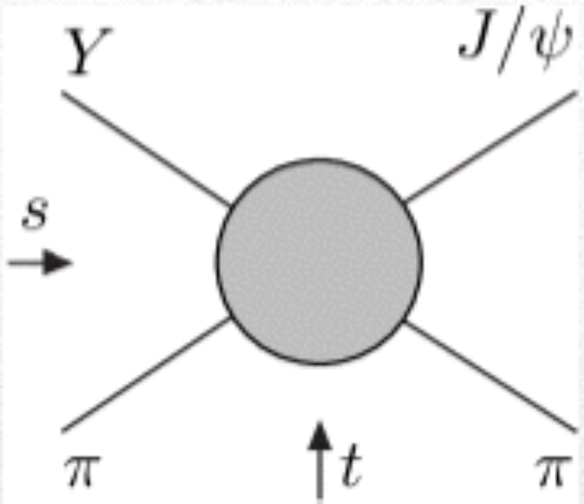
$0.100 < t' < 0.113$ (GeV/c)^2

$\pi^- p \to \pi^- \pi^+ \pi^- p$ (COMPASS 2008)

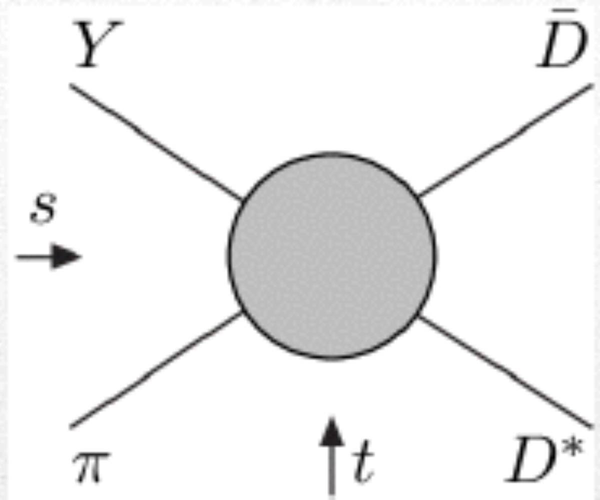


M.Mikashenko, in preparation

$Z_c(3900)$



Channel 1



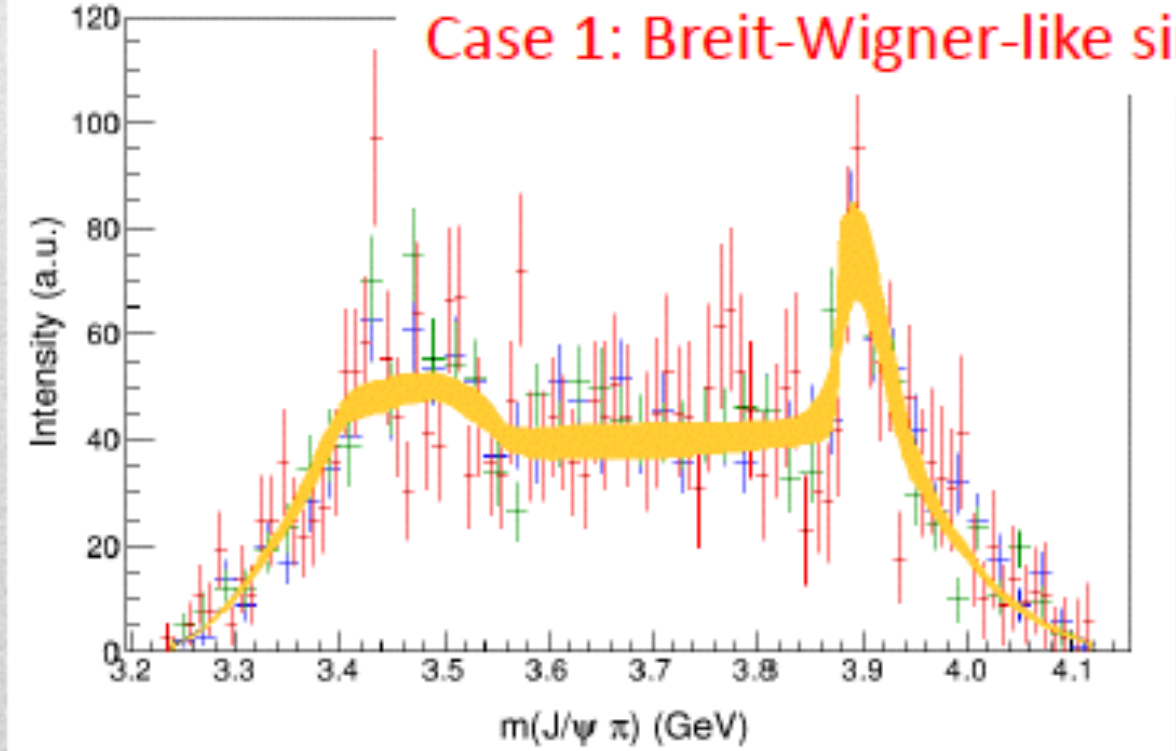
Channel 2

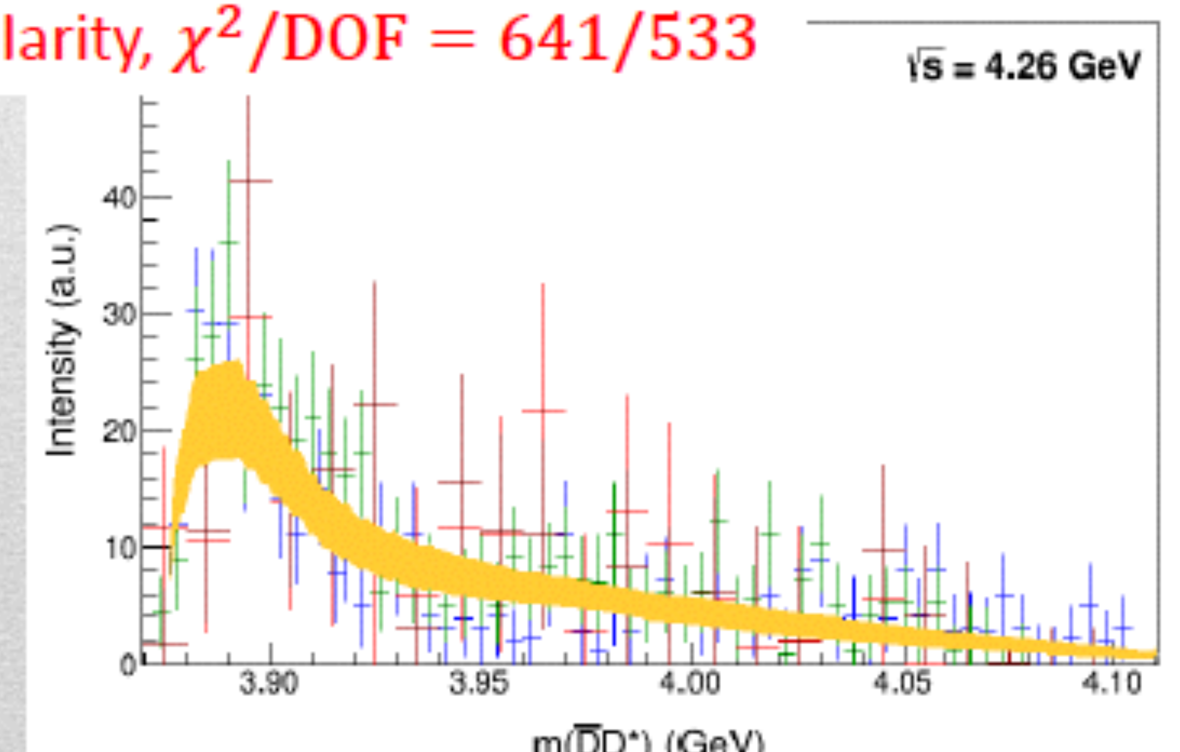
Scattering matrix, can (or not) have the Z_c pole

$$f_{0,i}(s) = b_{0,i}(s) + \frac{t_{ij}}{\pi} \int_{s_i}^{\infty} ds' \frac{\rho_j(s') b_{0,j}(s')}{s' - s}$$

Cross channel exchanges, contain log. branching point

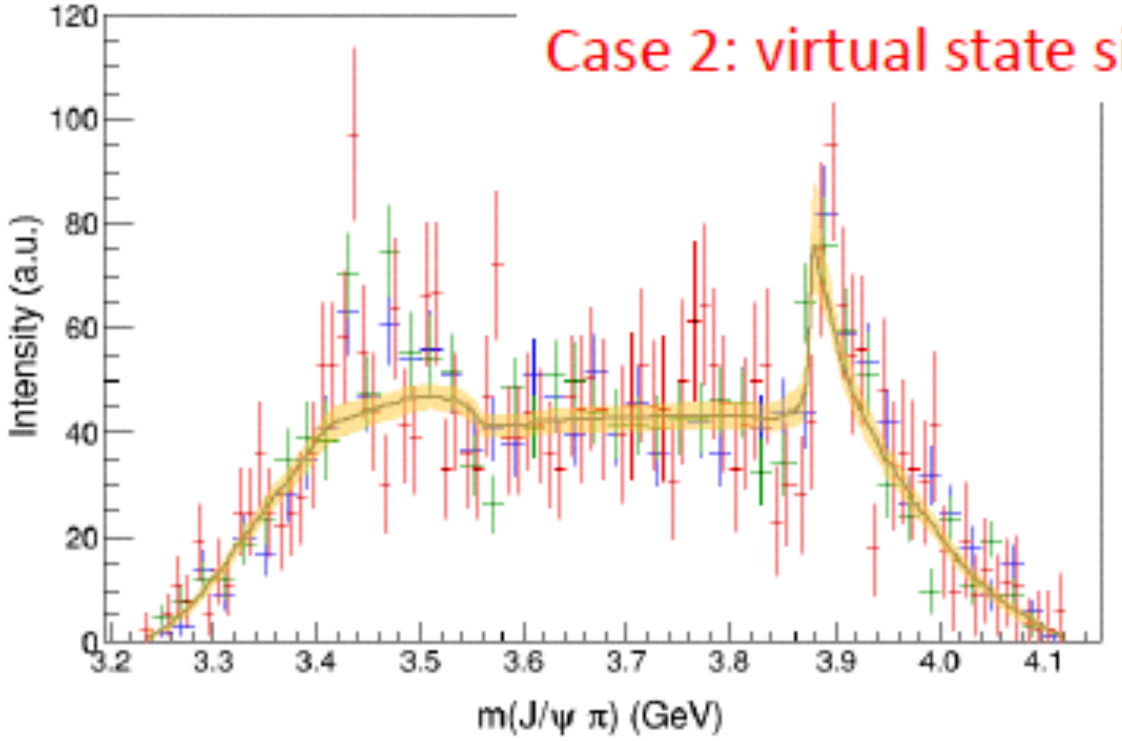
Case 1: Breit-Wigner-like singularity, $\chi^2/\mathrm{DOF} = 641/533$

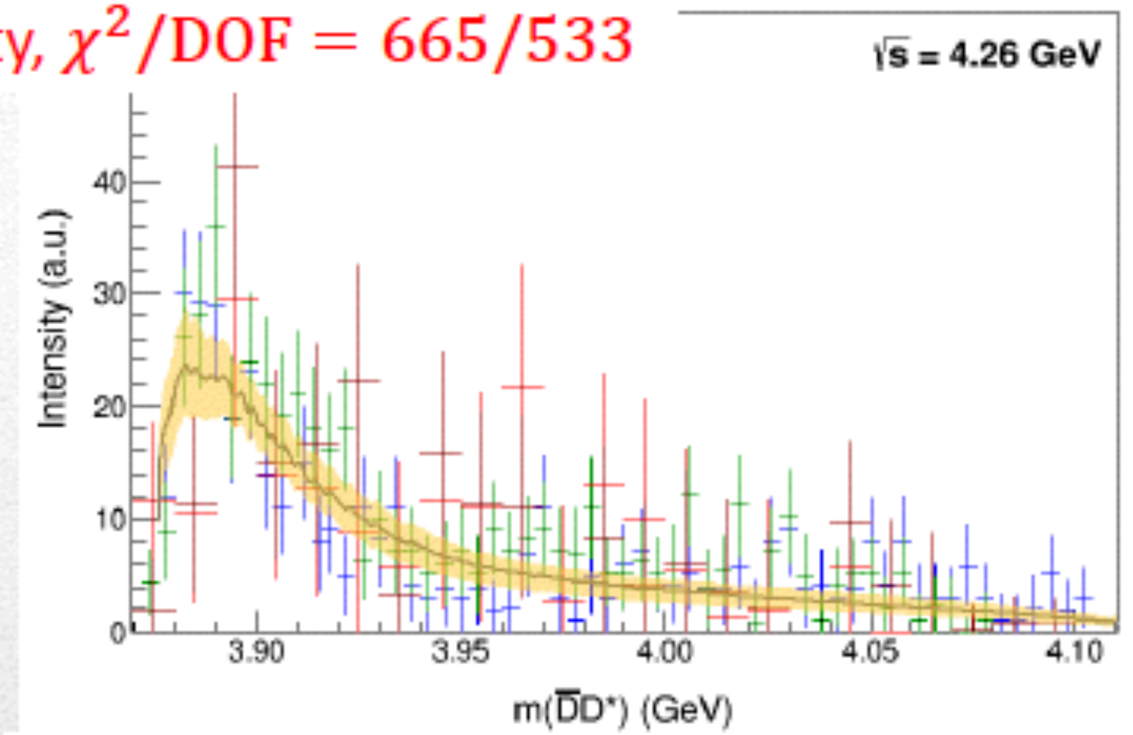




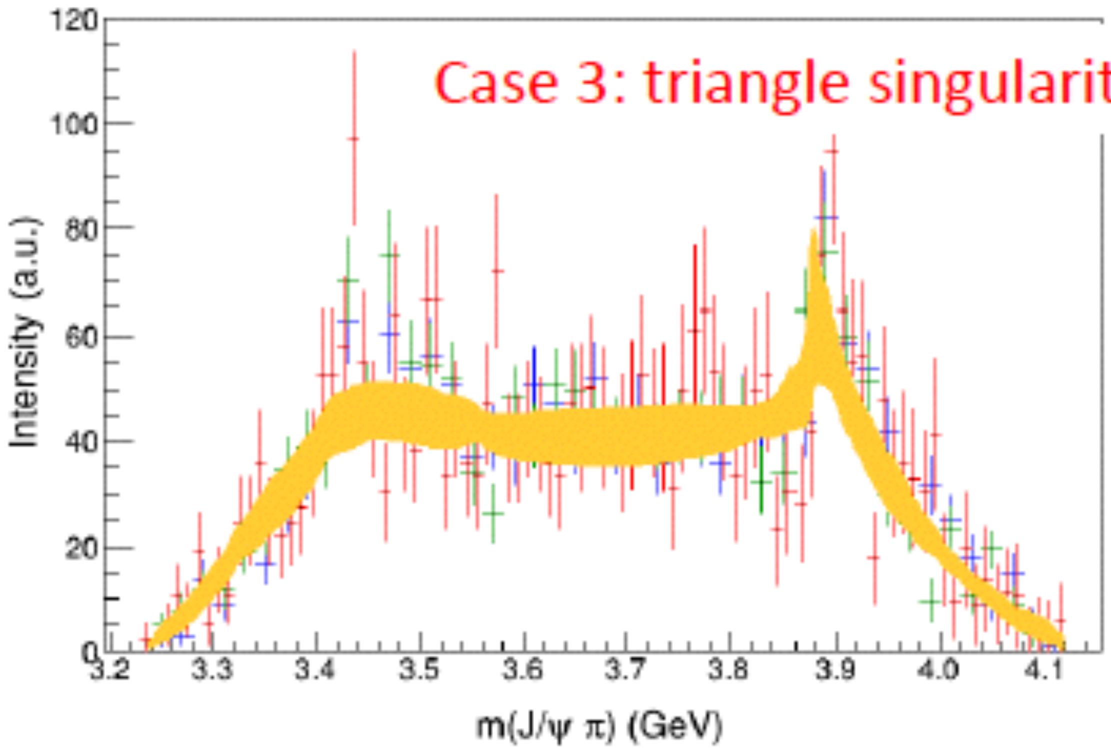
A.Piloni, in preparation

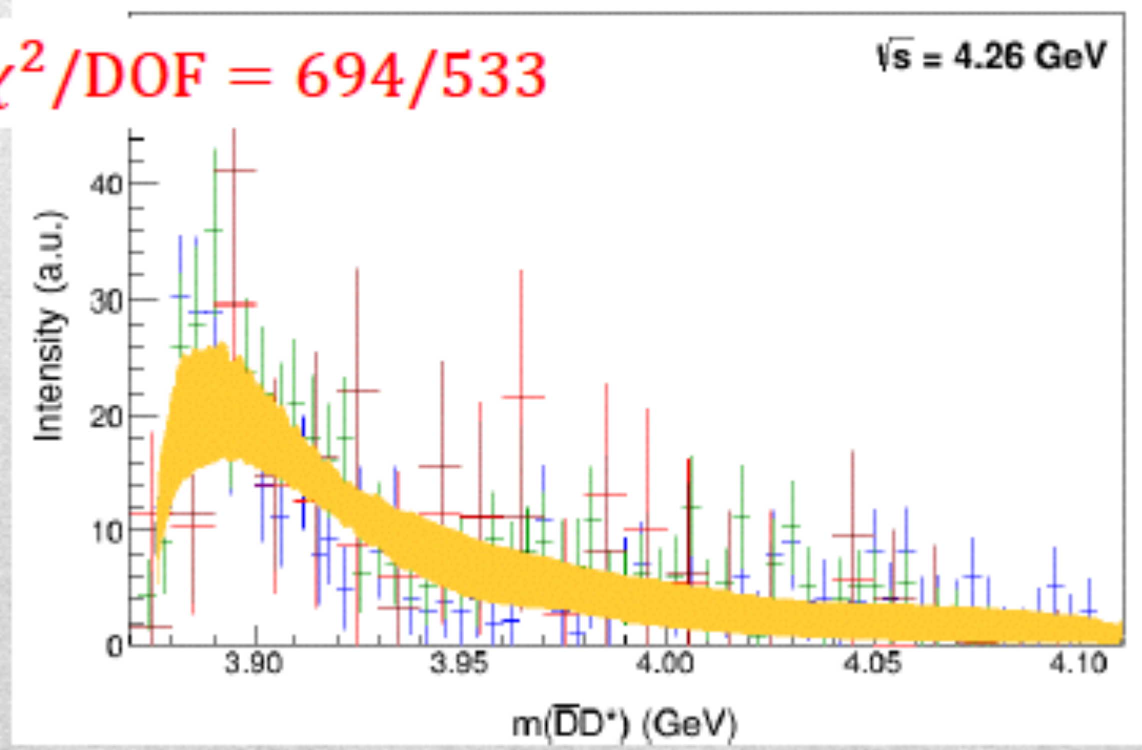
Case 2: virtual state singularity, $\chi^2/\mathrm{DOF} = 665/533$





Case 3: triangle singularity only, $\chi^2/\mathrm{DOF} = 694/533$

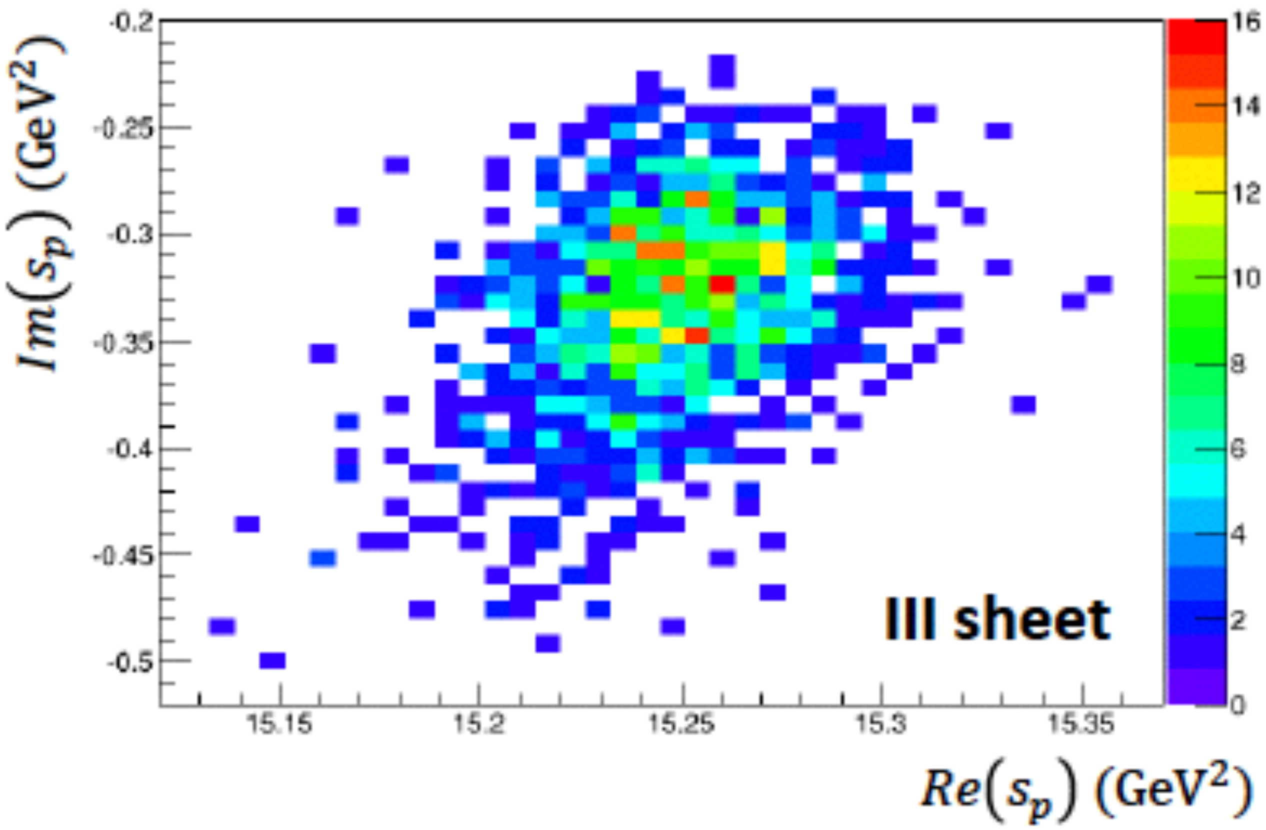




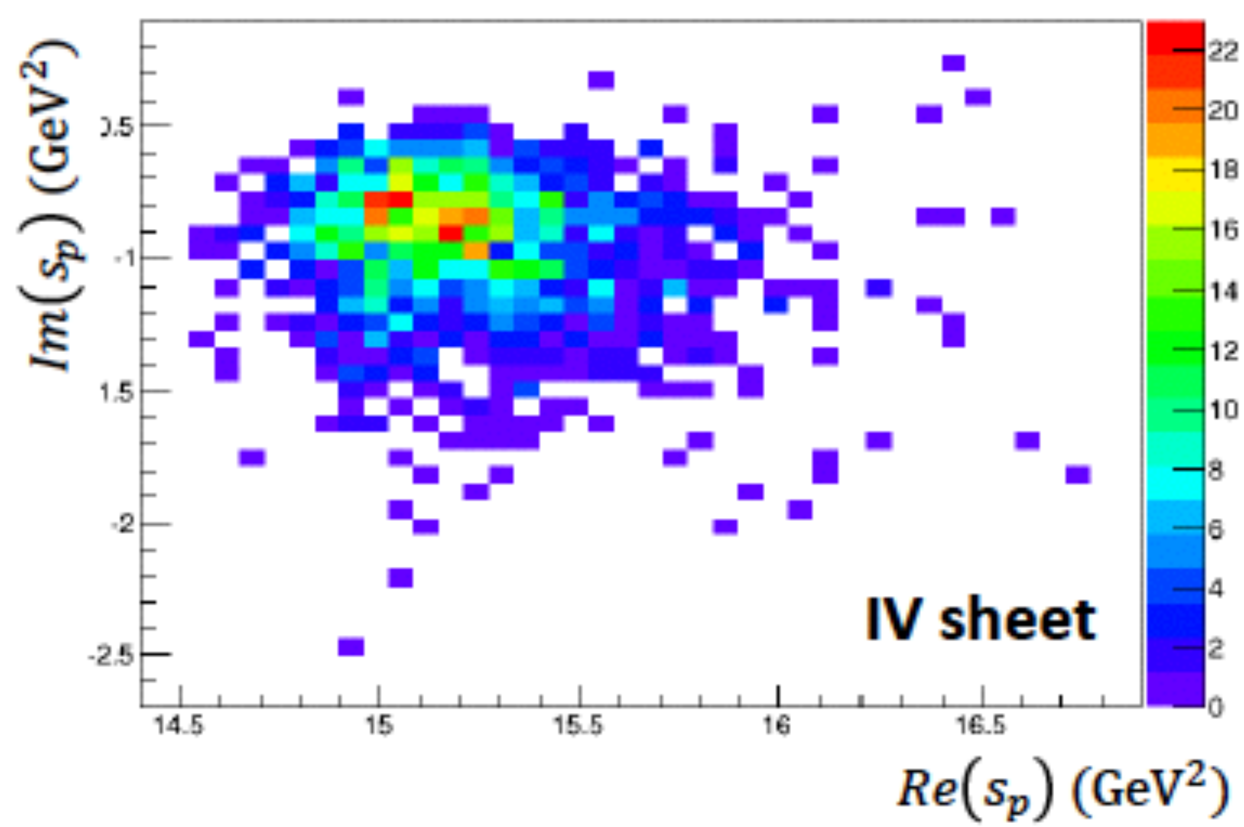
No strong conclusion can be driven yet, but we are establishing the method to use when higher statistics will be available

Pole position

Case 1: Breit-Wigner-like singularity



Case 2: virtual state singularity



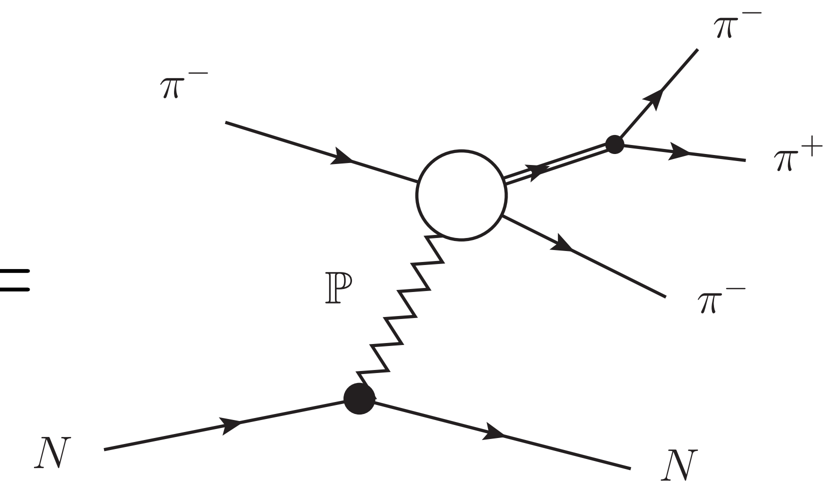
Other activities

- In talks with PARTON's project (Pawel Sznajder et al.)
- Amplitude analysis for baryon (CLAS12) spectroscopy program (with Victor M. and Dan C.)
- Affiliated memberships : LHCb (approved) BESIII (in discussions)
- Summer School on Reaction Theory (June, 2017)
- FDHS Workshop (Sept., 2017 Mexico City)
- Work days (2-3 planed for 2017)

COMPASS $\pi^- N \to \pi^- \pi^- \pi^+ N$

JPAC working with COMPASS on modeling amplitudes for mass-independent fits

$A =$



- Model emphasizes production process and unitarity
- Use isobar assumption in two pions $\quad (\pi^-\pi^+) \to \rho(770), f_2(1270), \ldots$
- Amplitude factorization

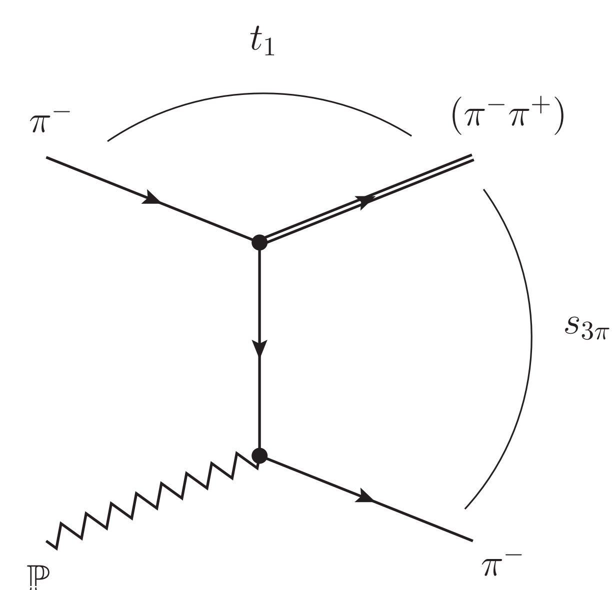
$\pi^- \mathbb{P} \to (\pi^-\pi^+)\pi^-$ Vertex

$$A = A(N \to \mathbb{P}N)A(\pi^- \mathbb{P} \to I_S \pi^-)A(I_S \to \pi^- \pi^+)$$

$N \to \mathbb{P}N$ Vertex

Isobar Decay

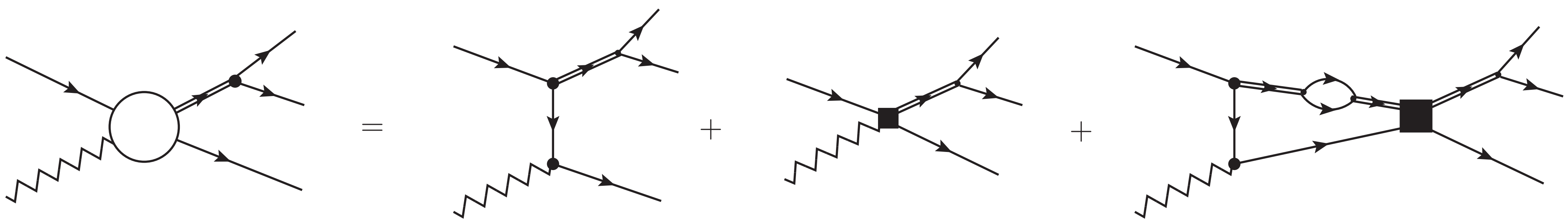
- Production Model: Pi-exchange
- Project amplitude to partial waves and use production model as input -> Fit parameters in rescattering amplitude



COMPASS $\pi^- N \to \pi^- \pi^- \pi^+ N$

- Model for partial wave amplitudes $F_i(s)$

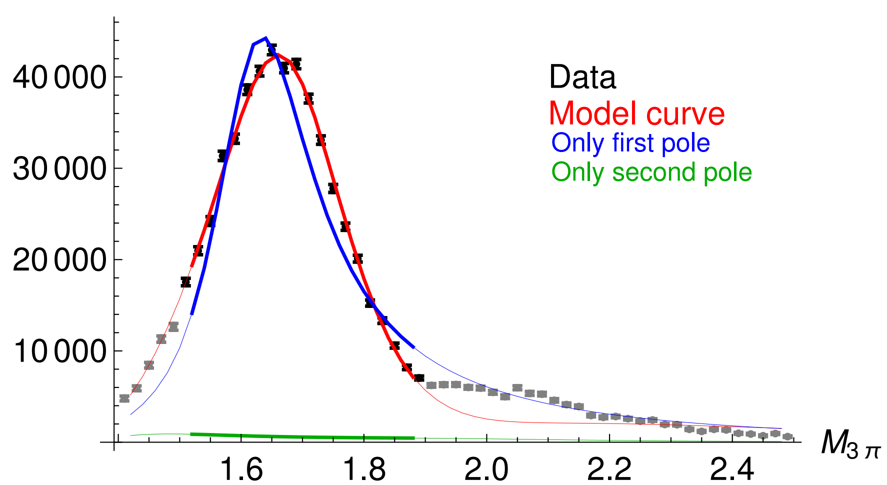
$$F_i(s) = b_i(s) + \sum_j t_{ij}(s) c_j + \frac{1}{\pi} \sum_j t_{ij}(s) \int_{s_j}^{\infty} ds' \frac{\rho_j(s') b_j(s')}{s' - s}$$



- Compare intensity distributions of our amplitude to COMPASS
- Currently performing full analysis on high event channels

$$I_i(s) = \int d\Phi_3 \, |F_i(s)|^2$$

$f_2 \pi \;\; S - \text{wave}$



$f_2 \pi \;\; D - \text{wave}$