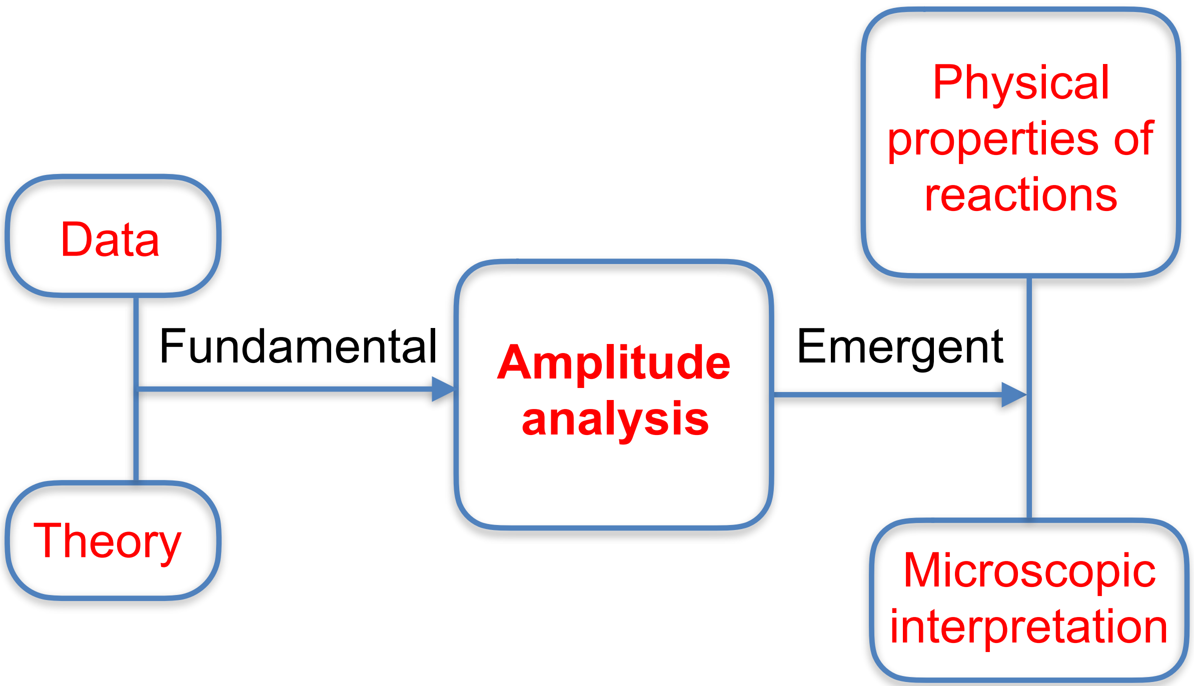
Update from JPAC

Adam Szczepaniak, Indiana University/Jefferson Lab

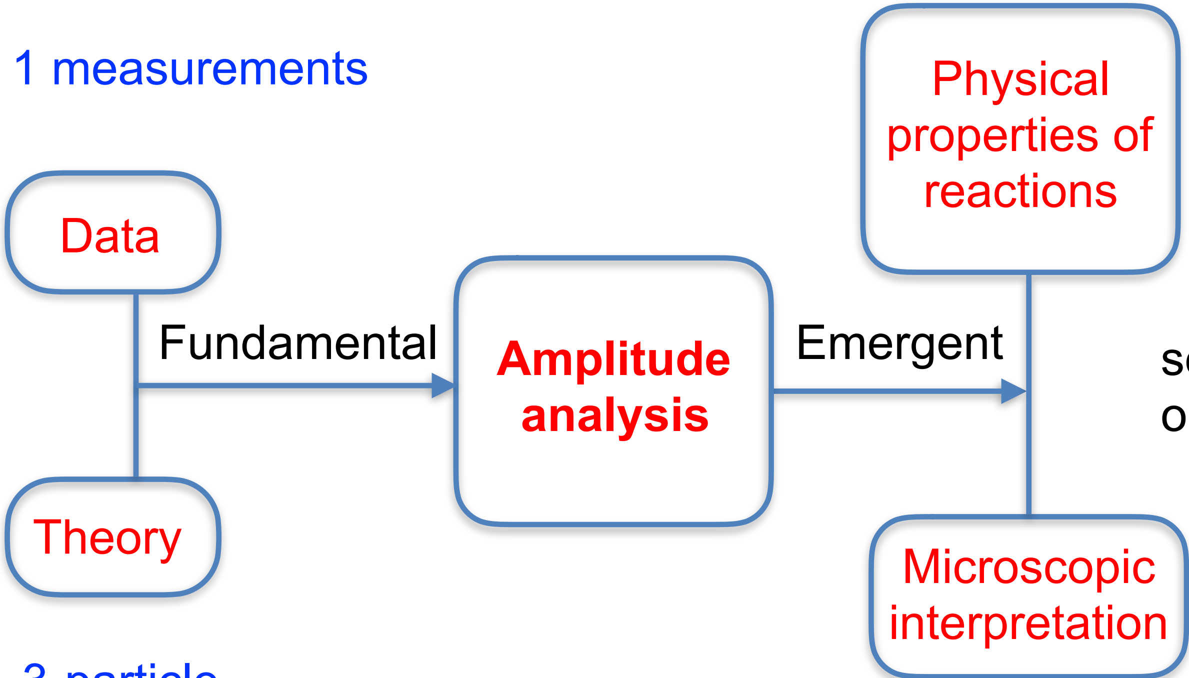


Update from JPAC

Adam Szczepaniak, Indiana University/Jefferson Lab

- LS vs covariant amplitudes

- Day 1 measurements



see Vincent Mathieu on Thursday

- 3-particle scattering

- Confinement though QCD correlation functions
- Quark Model is back

Jefferson Lab

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Victor Mokeev
Emilie Passemar[1]
Adam Szczepaniak[1]
Vladiszlav Pauk
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Peng Guo

Pedagogical U Kraków

Lukasz Bibrzycki

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Vincent Mathieu
Andrew Jackura
Nathan Sherrill
Daniel Winney
Sebastian Dawid

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Igor Danilkin

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Astrid Hiller Blin

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Ghent Universiteit

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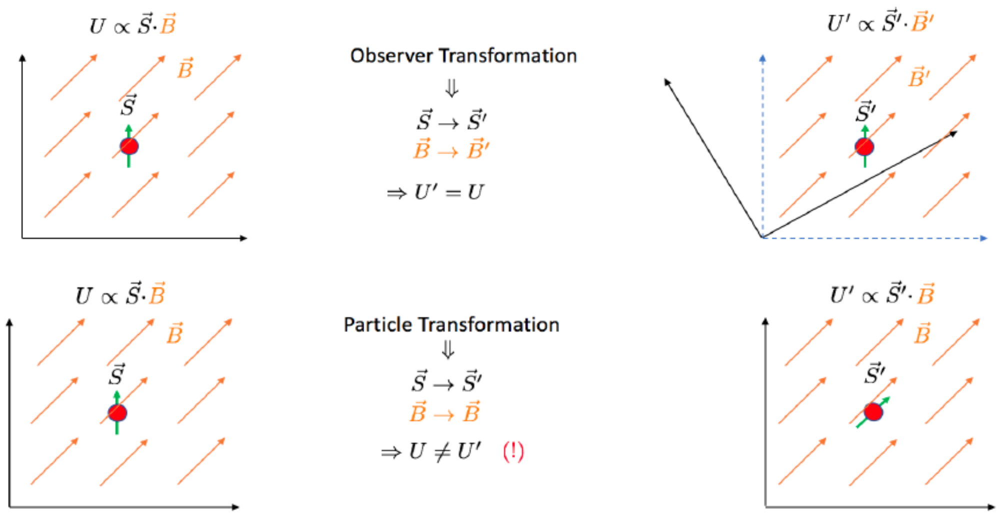
PhD student
[1]JLab/GWU funded
[2]JLab/IU funded

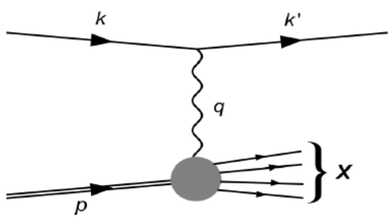
Collaborating with: CLAS12 & GlueX (JLab), COMPASS & LHCb (CERN), MAMI (Mainz), BESIII (Beijing), KLOE (Frascati), BELLE II (KEK), BABAR (SLAC)

(Very) exotic physics: constraining Lorentz symmetry violation



- Observer transformations do not affect results.
- Particle transformation, e.g. rotation of the experiment in the background filed produces a physical effect.

- There is a well defined SME $\mathcal{L}_{SME} = \mathcal{L}_{Gravity} + \mathcal{L}_{SM} + \mathcal{L}_{LV}$ e.g $a_\mu \bar{\psi}\gamma^\mu\psi,\ c_{\mu\nu}\bar{\psi}\gamma^\mu \overleftrightarrow{D}^\nu\psi$
(D.Colladay & V.A. Kostelecky, PRD55, 6760 (1997); PRD58, 1166002 (1998); PRD69, 105009 (2004))
- Only a few constraints in the quark sector : use DIS, SDIS, Drell-Yan, …



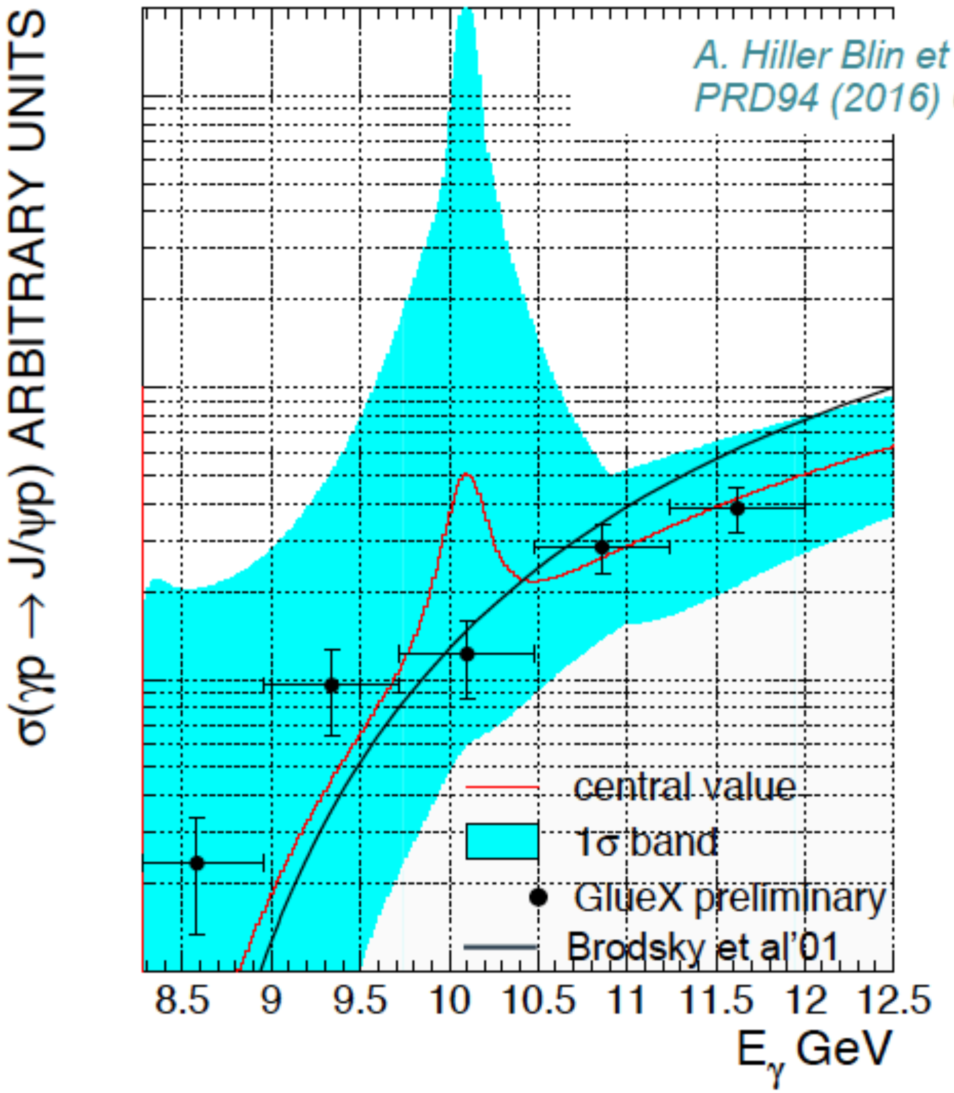
$$W^{\mu\nu} \simeq i \int d^4x e^{iq\cdot x} \int_0^1 d\xi \sum_{f=u,d} \frac{f_f(\xi)}{\xi} \langle \xi P| T\{J^\mu(x) J^\nu(0)\} |\xi P\rangle$$

$$\Gamma_f^\mu = \gamma^\mu + c_f^{\mu\nu}\gamma_\nu$$

- The first estimate on the sidereal time dependent coefficients c_f were obtained using HERA data: $O(10^{-5})$
(V.A.Kostelecky, E.Lunghi, A.Vieira, PLB729, 272 (2017))
- Sensitivity studies for EIC are under way: N.Sherrill, A.Accardi, E.Lunghi. Possible interest for CLAS12 ?

Exotic physics: P_c at JLAB

Confirmation possible thorough photoproduction



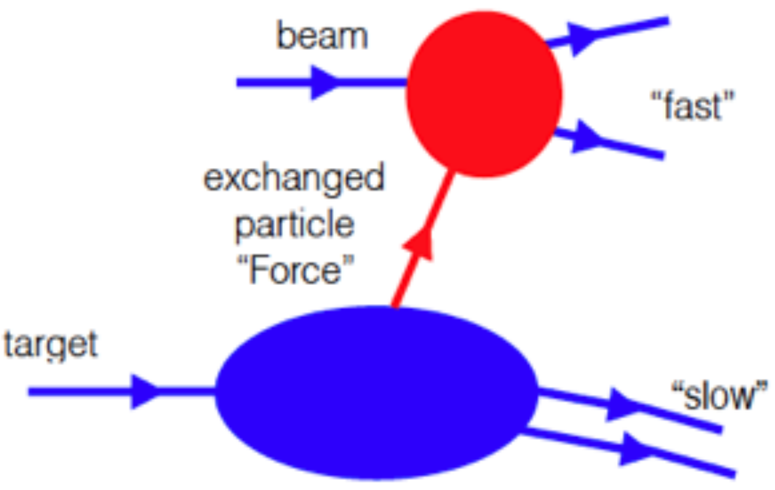
If P_c is confirmed, need to:

- Study the electromagnetic properties
- Look for the other members of the P_c multiplet
- Investigate its nature on the model of *A. Pilloni et al., Phys.Lett. B772 (2017) 200*
- NB: Arbitrary normalization for data

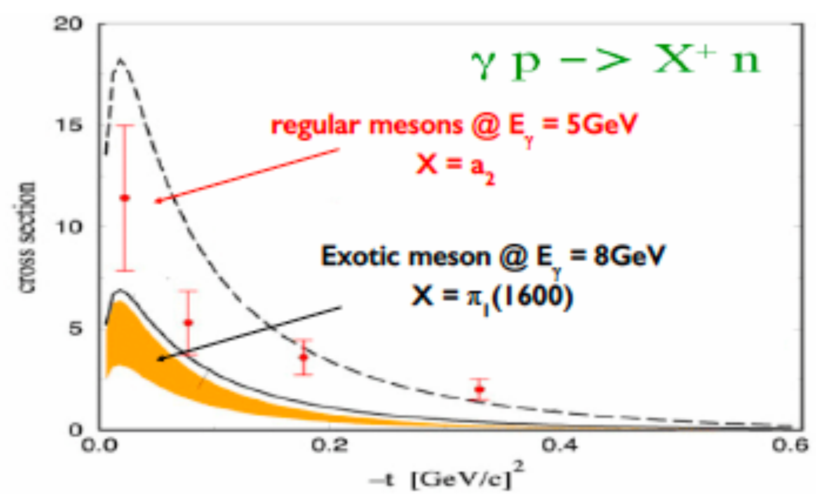
S.J. Brodsky, E. Chudakov , P. Hoyer, J.M. Laget
Phys.Lett. B498 (2001) 23-28

CLAS12: Day 1 experiments

- Early experiments can take advantage of the high ɣ photon energy to study production mechanisms.
- Exchange mechanisms determine formation of resonances (in top and bottom vertex)
- Electroproduction: t-channel mesons vs quarks (GPD'S) (with C.Wise)
- Factorization: Couplings can be compared with theoretical predictions
- One Pion Exchange is special (OPE): Pion from factor, transverse size of the nucleon, probe of physics beyond factorization.



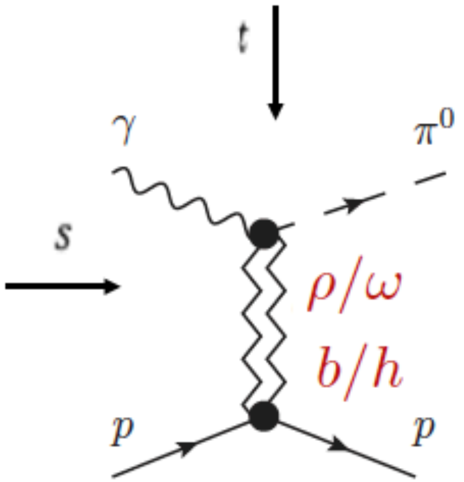
A. Afanasev and P. Page et al. PR A57 1998 6771
A. Szczepaniak and M. Swat PLB 516 2001 72



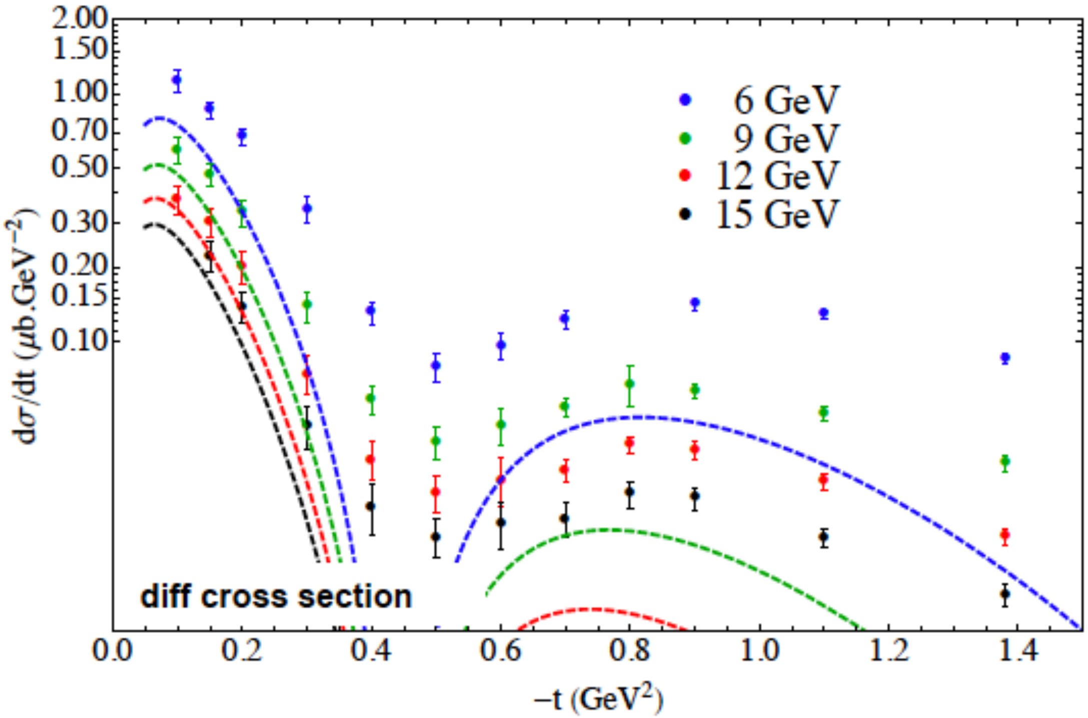
Resonance production at JLAB 12GeV

Establishing factorization

V. Mathieu et al., PRD92 (2015) 074013
J. Nys et al., PRD95 (2017) 034014

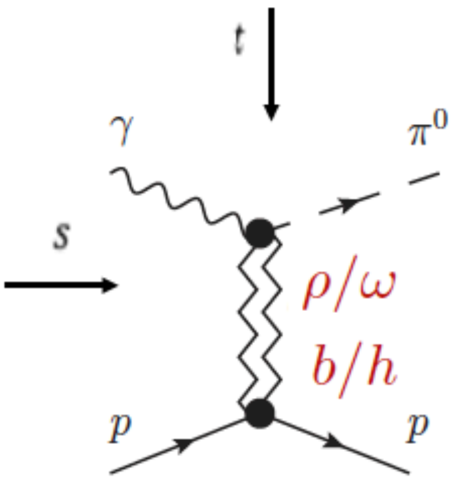


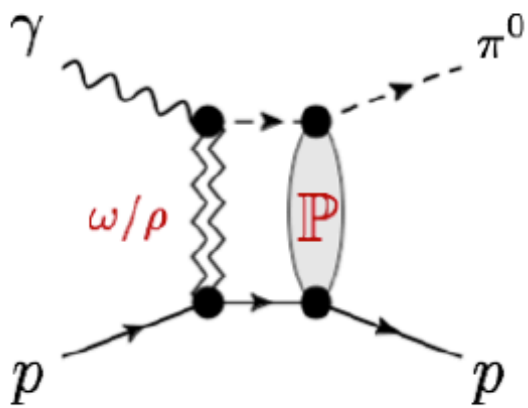
Key to determine separation meson from baryon resonance production



Resonance production at JLAB 12GeV

Establishing factorization





V. Mathieu et al., *PRD92 (2015) 074013*
J. Nys et al., *PRD95 (2017) 034014*

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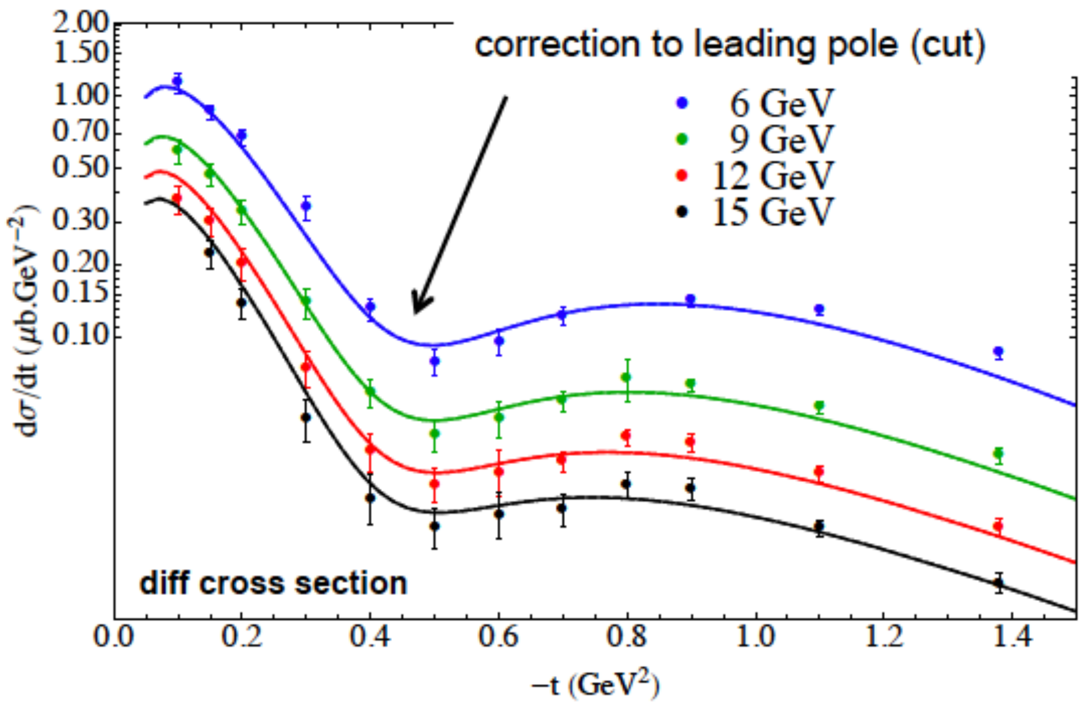
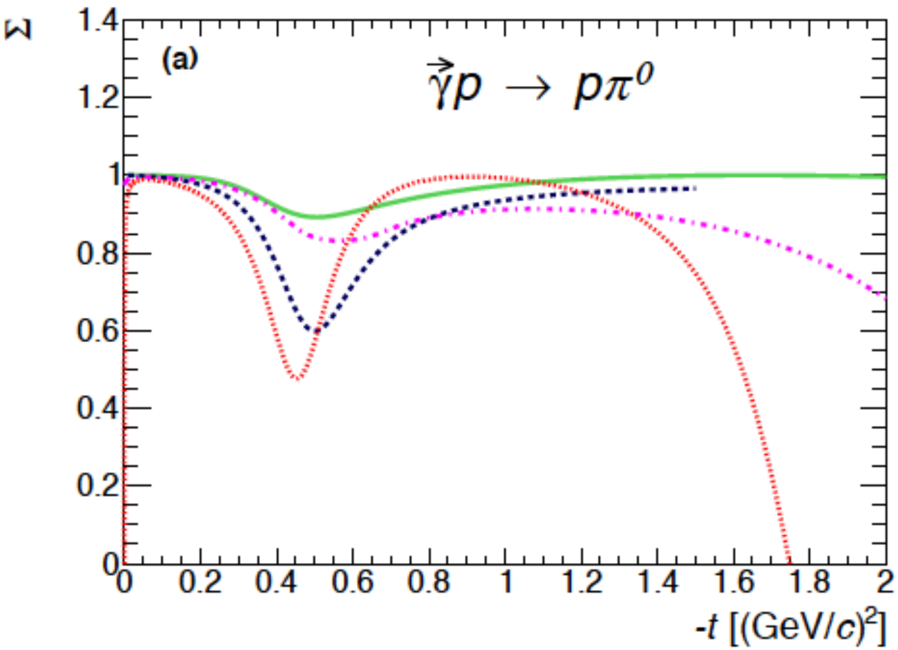
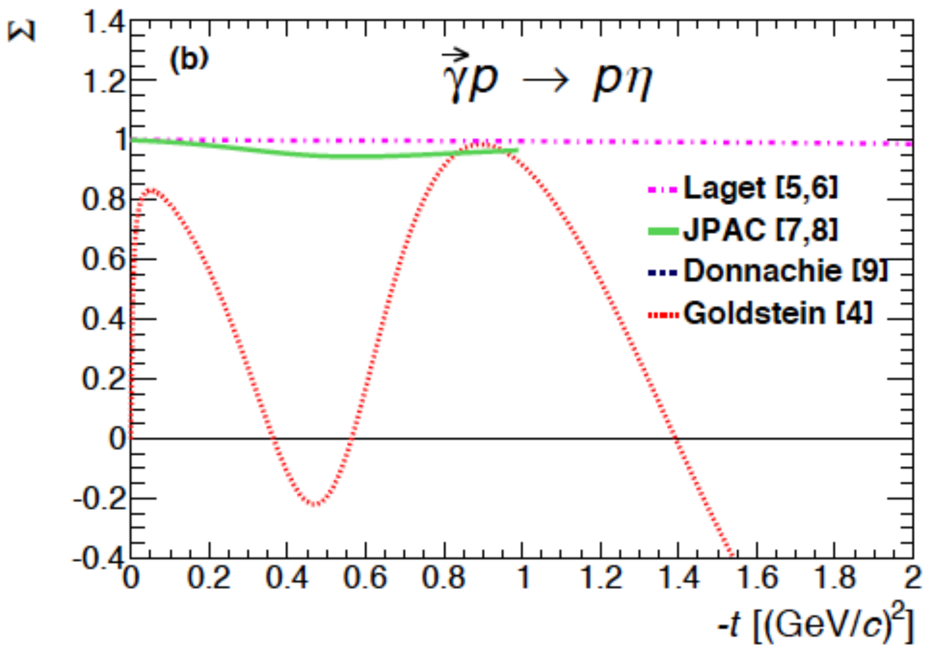


Beam asymmetry: measurement of the exchange process

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

- Photoproduction of neutral pseudo-scalars





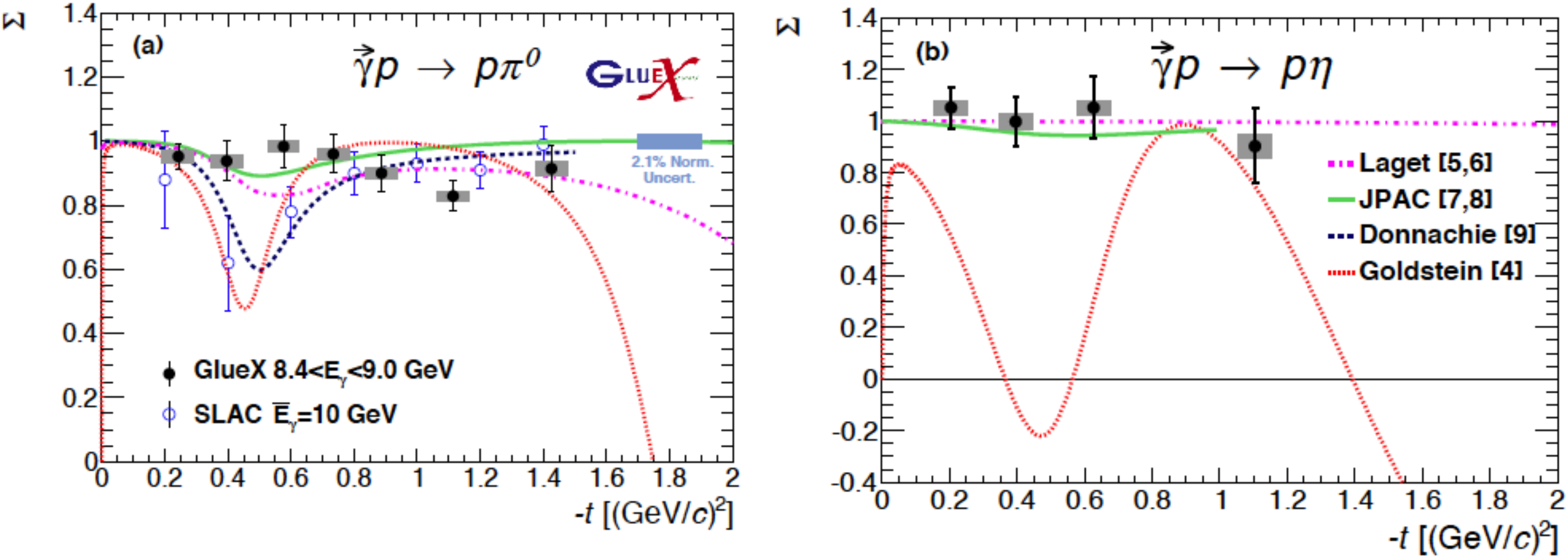
- JPAC prediction

V. Mathieu et al., PRD92 (2015) 074013
J. Nys et al., PRD95 (2017) 034014

Beam asymmetry: measurement of the exchange process

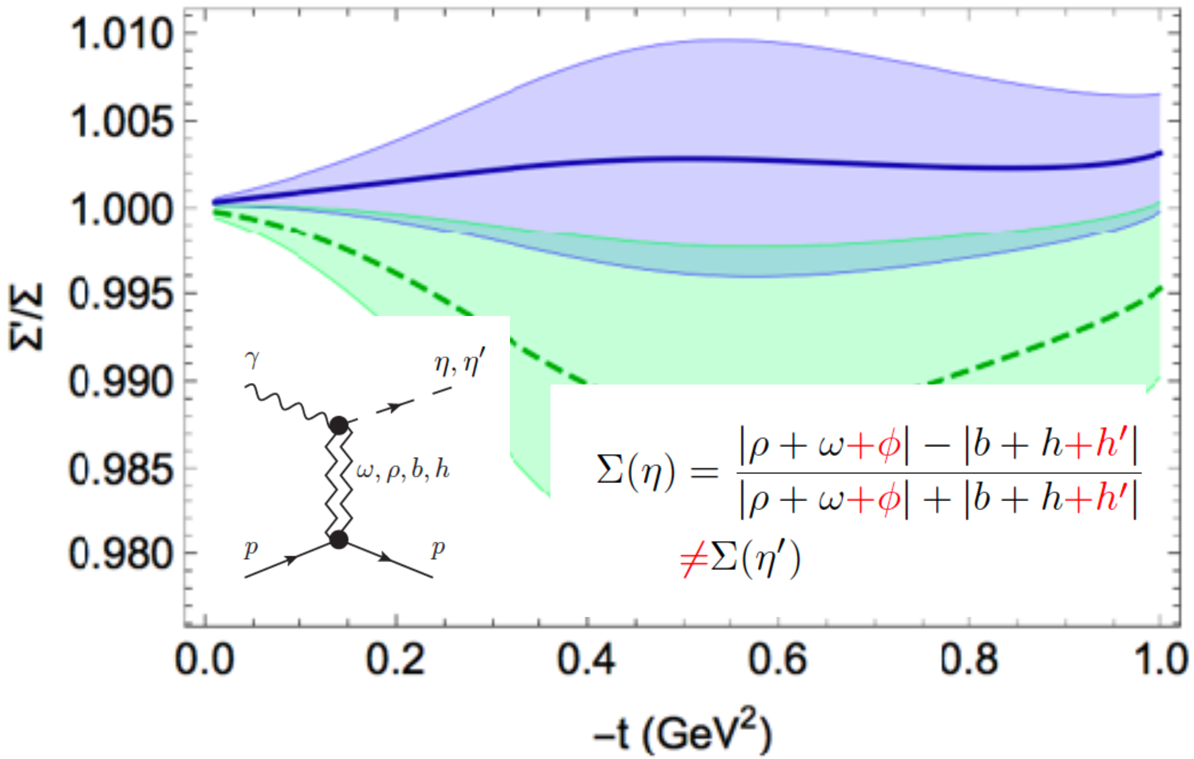
$$\Sigma = \frac{\sigma_\perp - \sigma_\parallel}{\sigma_\perp + \sigma_\parallel} = \frac{|\rho+\omega|^2 - |b+h|^2}{|\rho+\omega|^2 + |b+h|^2}$$

H. Al Ghoul et al. [GlueX]
Phys. Rev. C95 (2017) no.4, 042201
+V. Mathieu, J. Nys [JPAC]



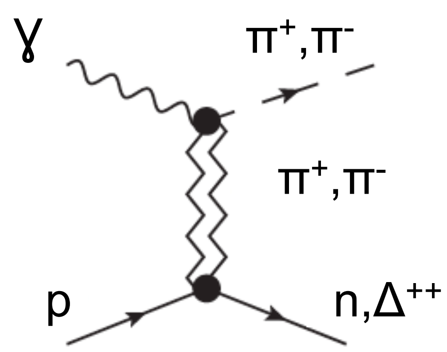
- Possible tension between GlueX and SLAC data ?

η/η' asymmetry probes coupling to strangeness



V.Mathieu et al. arXiv:1704.07684 (to appear in Phys. Lett. B)

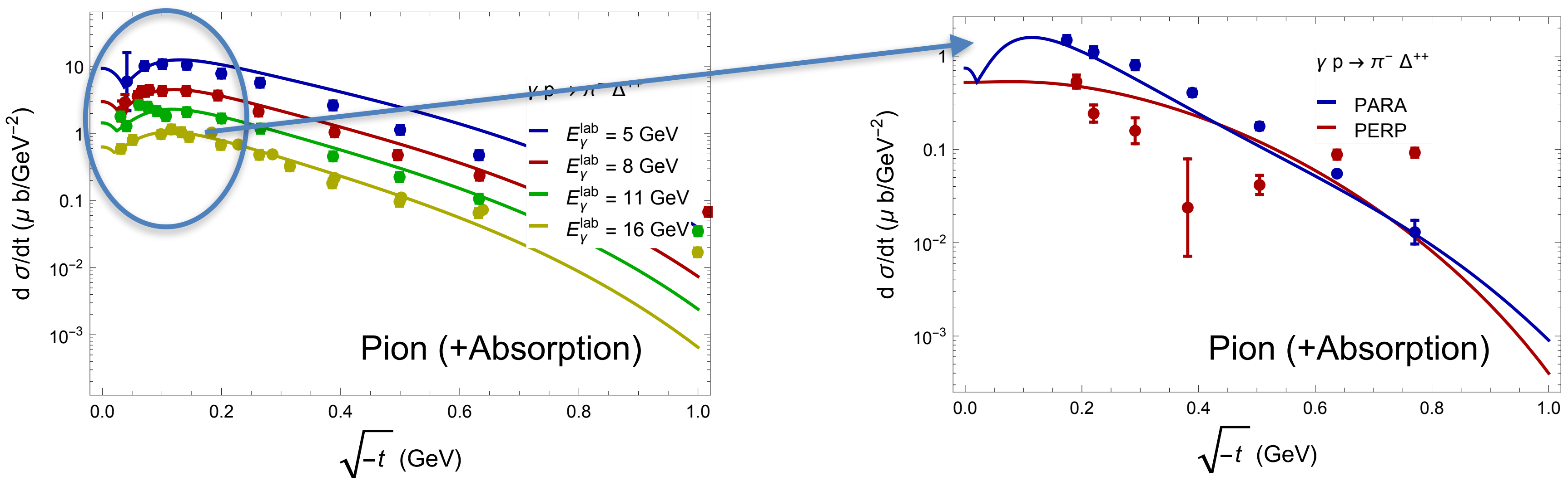
OPE is very interesting



- Factorized pion exchange

$$A_{\lambda_\gamma,\lambda,\lambda'} \sim \sqrt{t'}^{|\lambda_\gamma|}\sqrt{t'}^{|\lambda'-\lambda|}\frac{\beta(t)}{t-\mu^2}$$

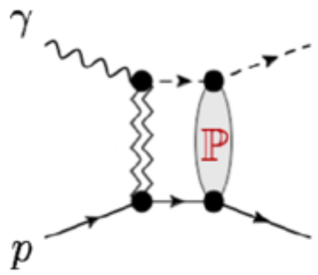
- Weak energy dependence ($\alpha_{eff} \sim 0$)
- Forward dip in dσ/dt



- Energy dependence ✔
- ρ/a_2 needed at large -t

- σ dominated by σ∥ (un natural exch.) > σ⊥ (natural exch.) ✔
- Forward dip ?

Absorption models and alternatives

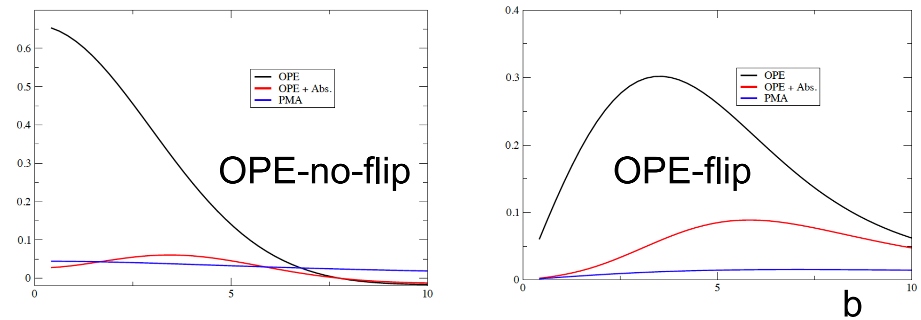


- Partial waves $l < l_{clas.}$ are absorbed by FSI. (b~lq):

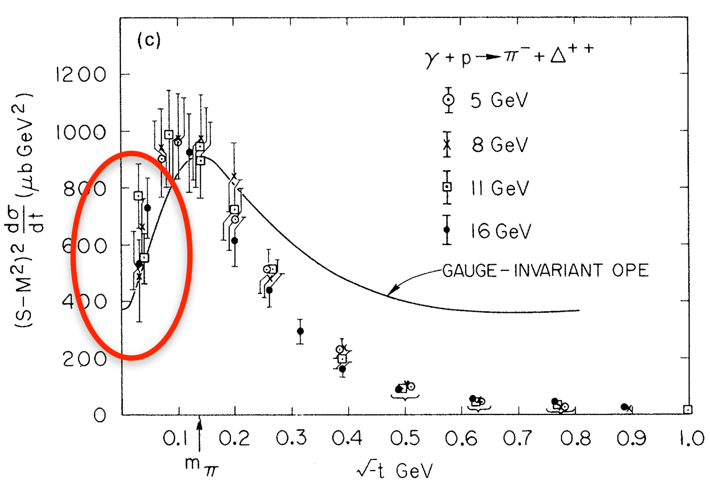
— Poor Man's Absorption (PMA)

— b-space

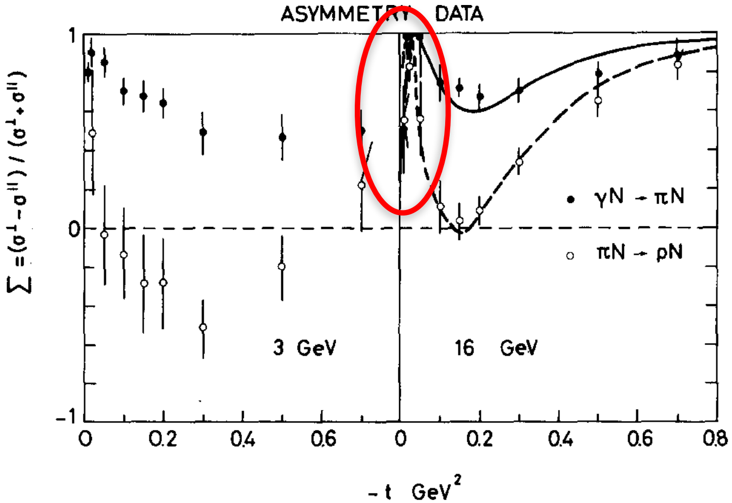
— s-channel



- Δ production



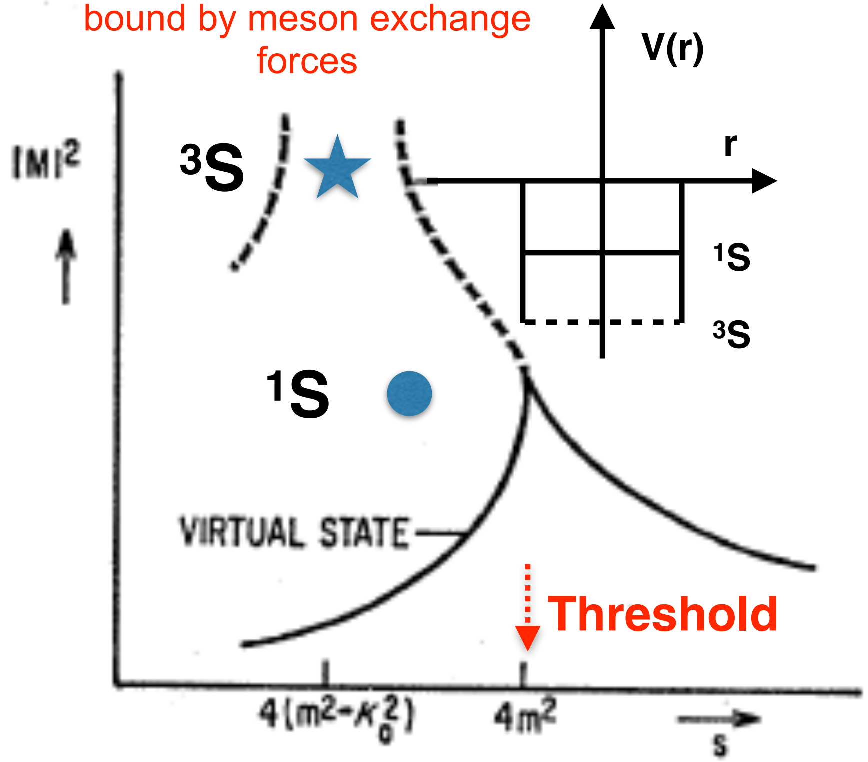
- N recoil



N,Δ production enable to study absorption mechanisms, eg. FSI dynamics

OPE’s role in binding

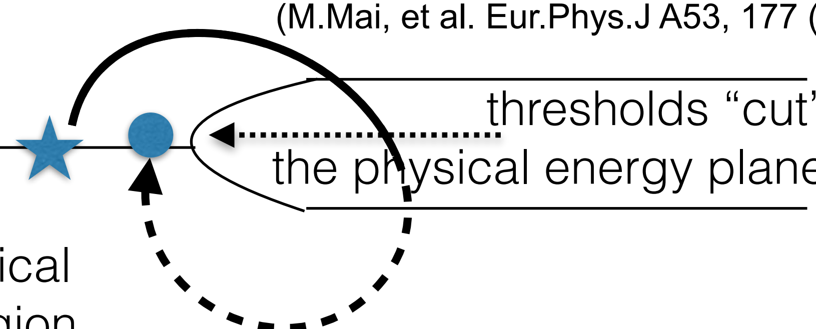
Deuteron the np molecule bound by meson exchange forces



- Threshold “states” are important because scattering amplitudes near threshold are universal.
- f0(980), a0(980), a1(1420), Lambda(1405), XYZ: These threshold “states” can potentially illuminate on the role of binding force, e.g. OPE
- In some cases virtual pion exchange can become real and three body formalism is required, e.g. $D^*\bar{D} \rightarrow X(3872) \rightarrow D\bar{D}\pi$

(M.Mai, et al. Eur.Phys.J A53, 177 (2017))

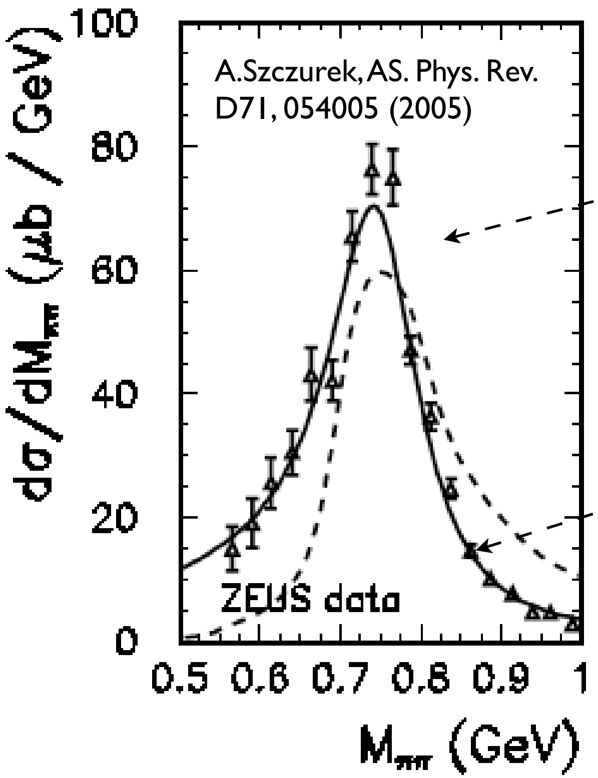
bound state : pole on the physical energy plane

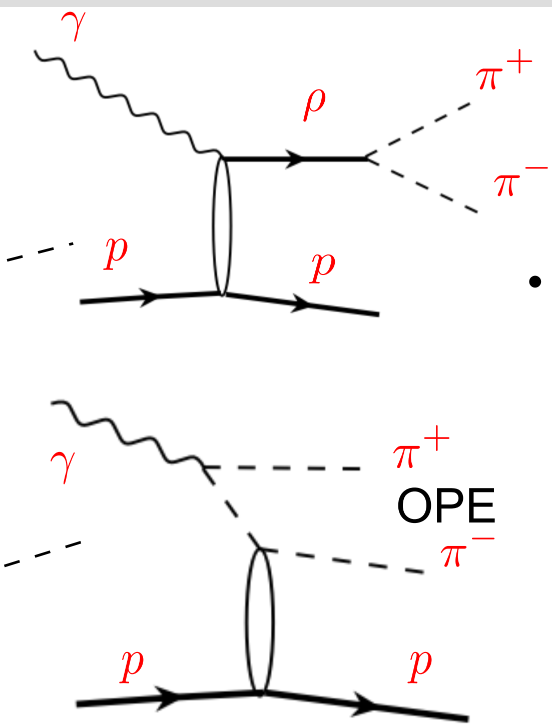


thresholds “cut” the physical energy plane

virtual state : pole on “unphysical sheet” closest the physical region

“Day 2” experiments

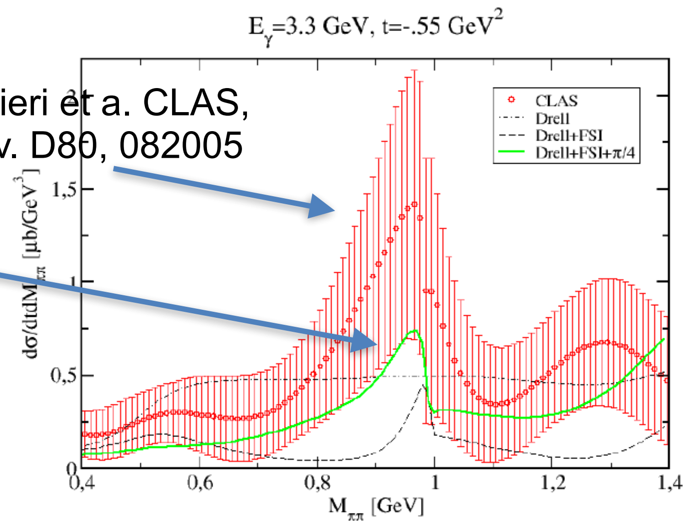




OPE

- Interference produces dips: Manifestation of long range exchange in resonance production

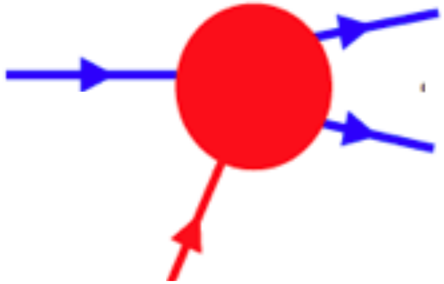
M.Battaglieri et a. CLAS, Phys. Rev. D80, 082005 (2009)



Ongoing JPAC analysis by L.Bibrzycki

Extension to $K\bar{K}$ and application to f-mesons (see K.Hicks)

Is L-S formalism relativistic ?



- Helicity (H) or spin-orbit (LS) formalism
- Covariant projection (CP) (tensor) formalism

Jacob, Wick, Annals Phys. 7, 404 (1959)

Chung, PRD48, 1225 (1993)
Chung, Friedrich, PRD78, 074027 (2008)
Filippini, Fontana, Rotondi, PRD51, 2247 (1995)
Anisovich, Sarantsev, EPJA30, 427 (2006)

The common lore is that the former is nonrelativistic and the later takes into account the proper relativistic corrections…

But:

- Both approaches use partial waves as building blocks.
- H/LS are OK

$$A_{\lambda_i}(s,t) = \sum_J (2J+1) A^J_{\lambda_i}(s) d^J_{\lambda,\lambda}(z_s)$$

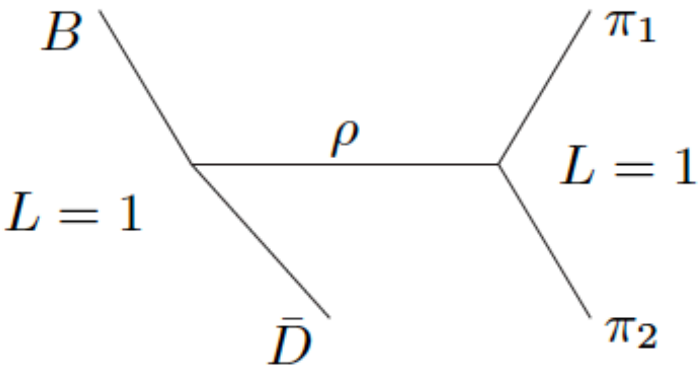
- CP reduces to H/LS with additional, (model) factors that depend on invariants

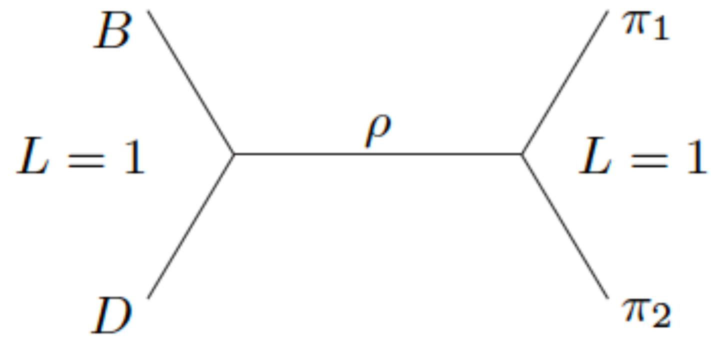
$$A_{\lambda_i}(s,t) = \sum_n M_n(\lambda_i) A_n(s,t)$$

- "Minimal" model dependence is "easiest" in the helicity-formalism. Care is needed in identifying kinematical vs dynamical singularities, limitations of the partial waves series, etc.

Crossing symmetry in CP formalism

A.Pilloni at HADRONS 17





The tensor amplitude is given by $p_D^{(B)} \cdot p_\pi^{(\rho)}$, where $p_D^{(B)}$ is the breakup momentum in the B frame, and $p_\pi^{(\rho)}$ the decay momentum in the isobar frame

$$A = \frac{m_{B^0}^2 + s - m_{h_3}^2}{2m_{B^0}^2} pq \cos\theta$$

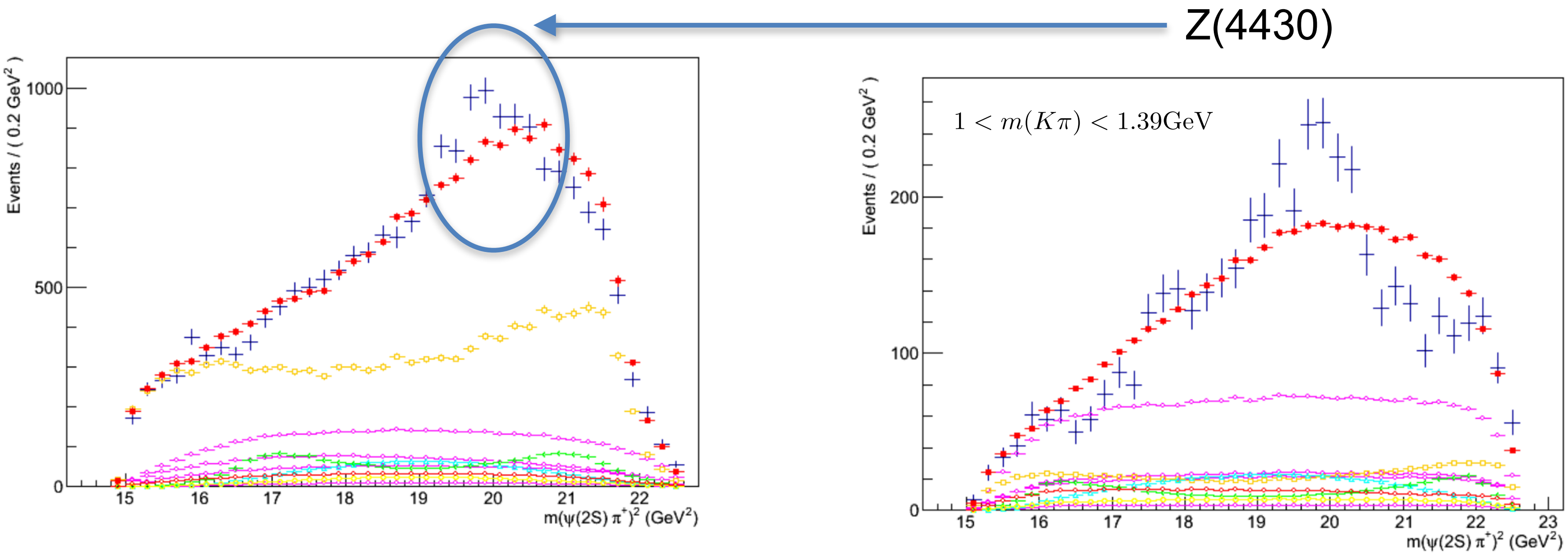
However, one can consider the scattering process just in the isobar rest frame.

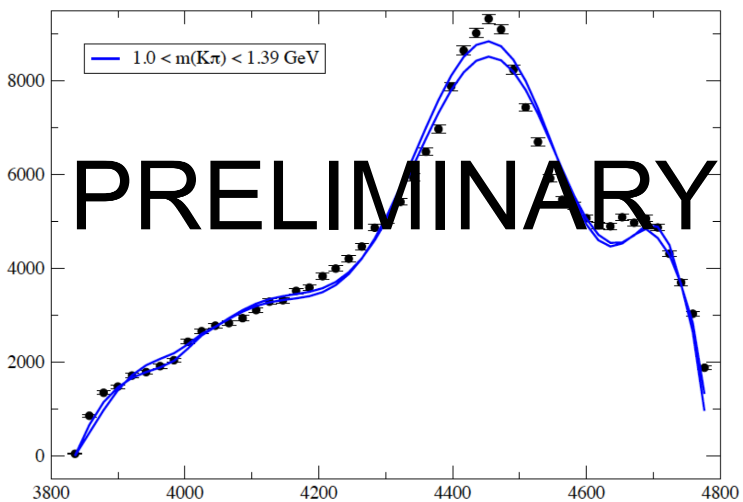
$$A = pq \cos\theta$$

By crossing symmetry the amplitudes must be the same.

The usual implementation fails crossing symmetry

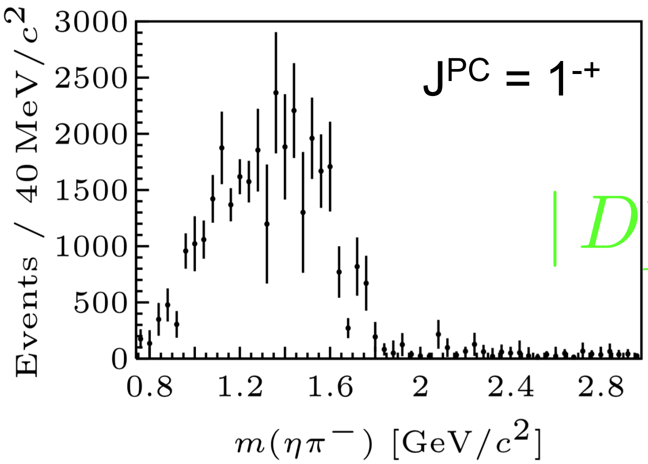
Example B → J/ψ π K



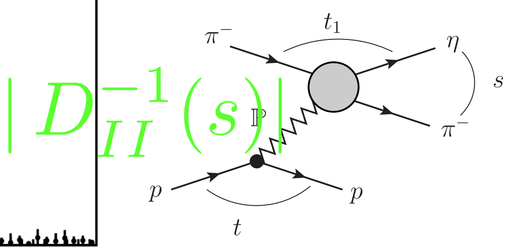


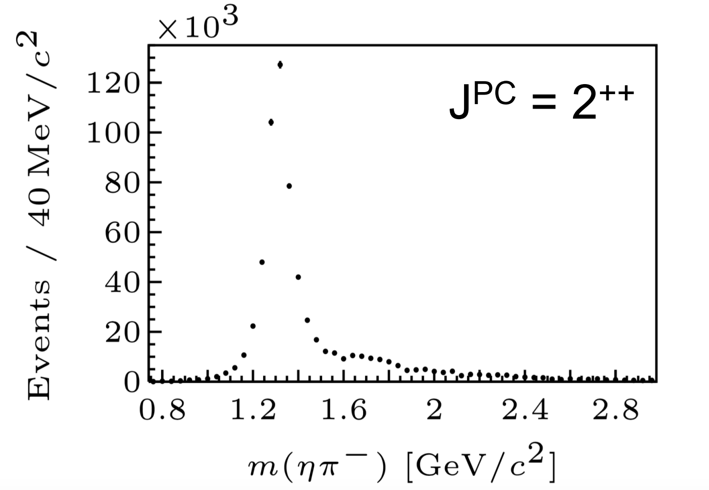
- Data : MC generated from for to LHCb data including the Z.
- Blue line : Fit using JPAC amplitudes with only K* resonances.
- Possible source of discrepancy: higher spin K*'s

Hybrid meson search golden channel: η(‘)π

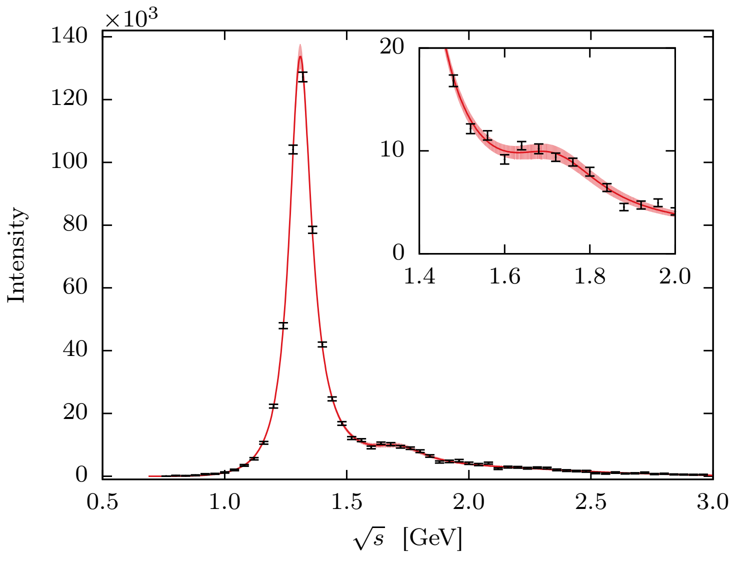


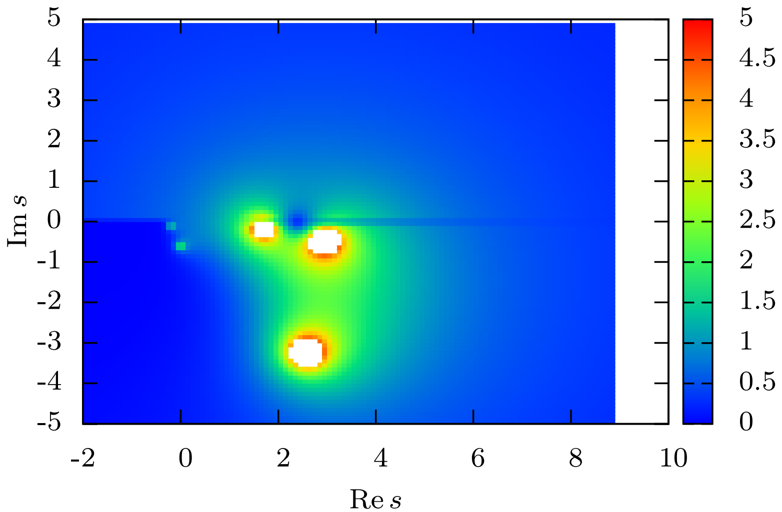
COMPASS



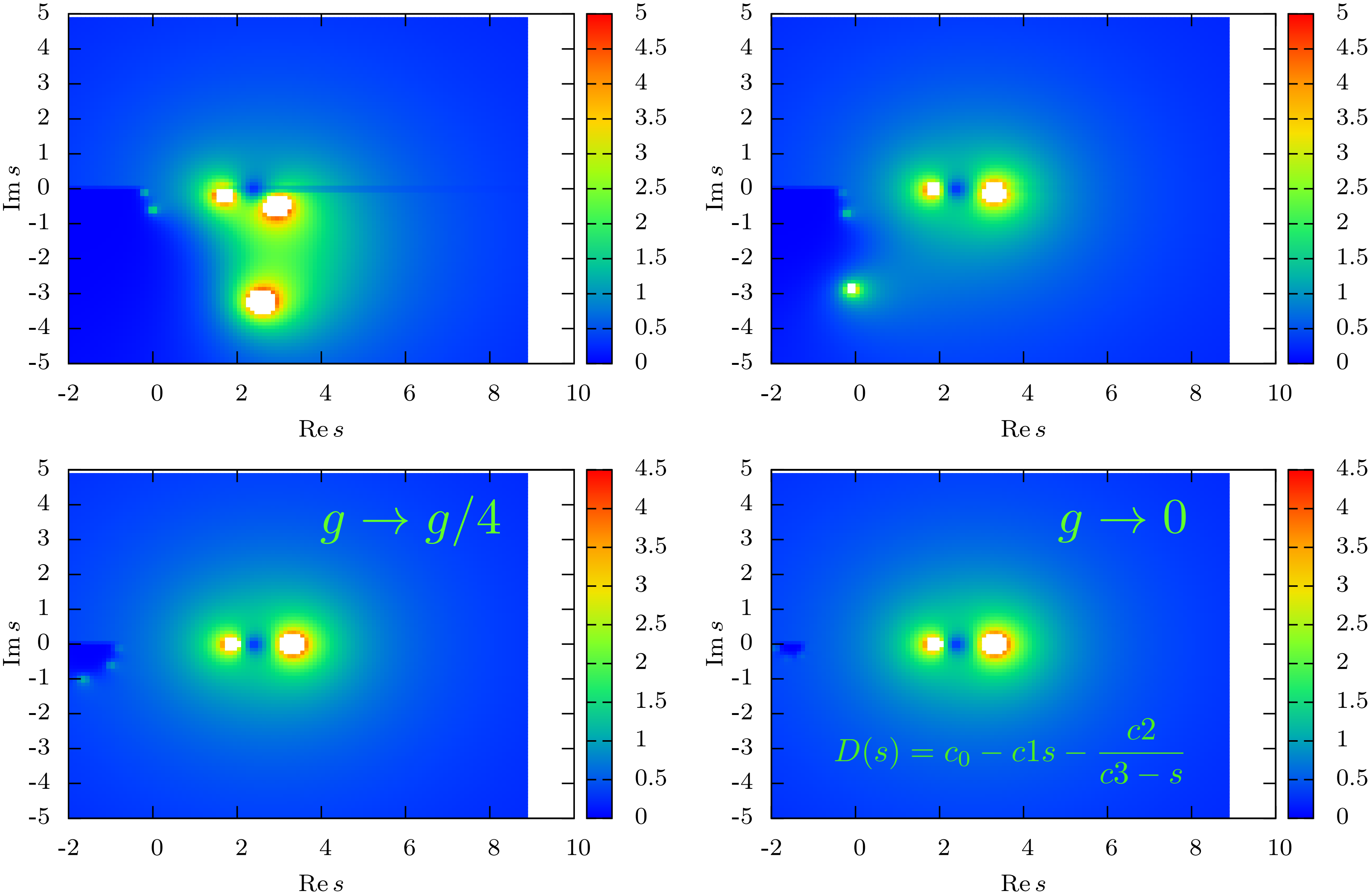


- Fit using N/D formalism with CDD poles
- Expect an narrow, $a_2(1320)$ resonance and determine parameters for the excited a'_2





Origin of the poles



More on impact

Summer School on Reaction Theory (IU, 2015 and 2017)

Plans for 2018 : Joint school with Mainz and/or BESIII