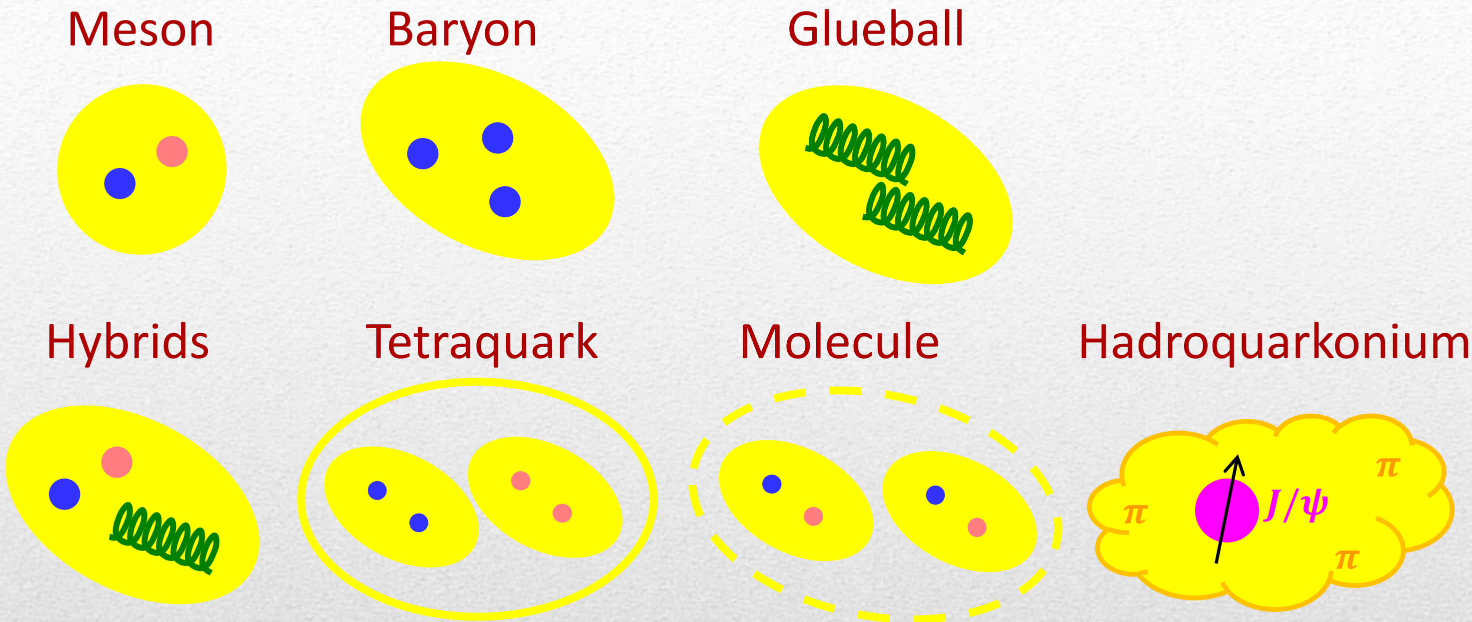
An update on JPAC activity

Alessandro Pilloni

Joint Physics Analysis Center

CLAS collaboration meeting, June 17th, 2016

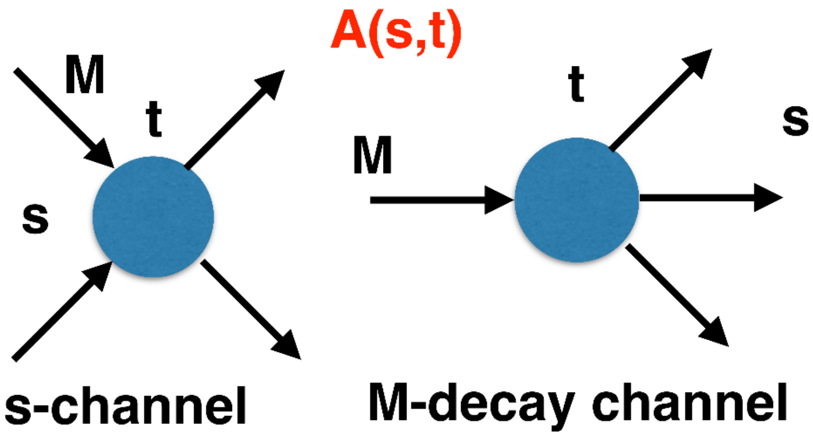
Hadron Spectroscopy



Data → Amplitude analysis (JPAC) → Spectrum and properties

Interpretations on the spectrum leads to understanding fundamental laws of nature

S-Matrix principles



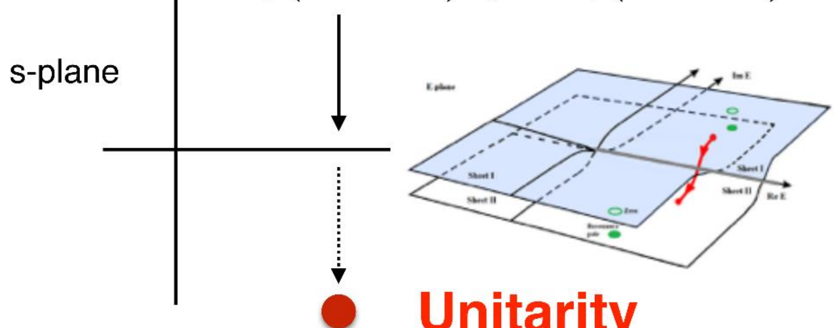
Crossing

$$A(s,t) = \sum_l A_l(s) P_l(z_s)$$

Analyticity

$$A_l(s) = \lim_{\epsilon \to 0} A_l(s + i\epsilon)$$

$$A_l(s + i\epsilon) \neq A_l(s - i\epsilon)$$



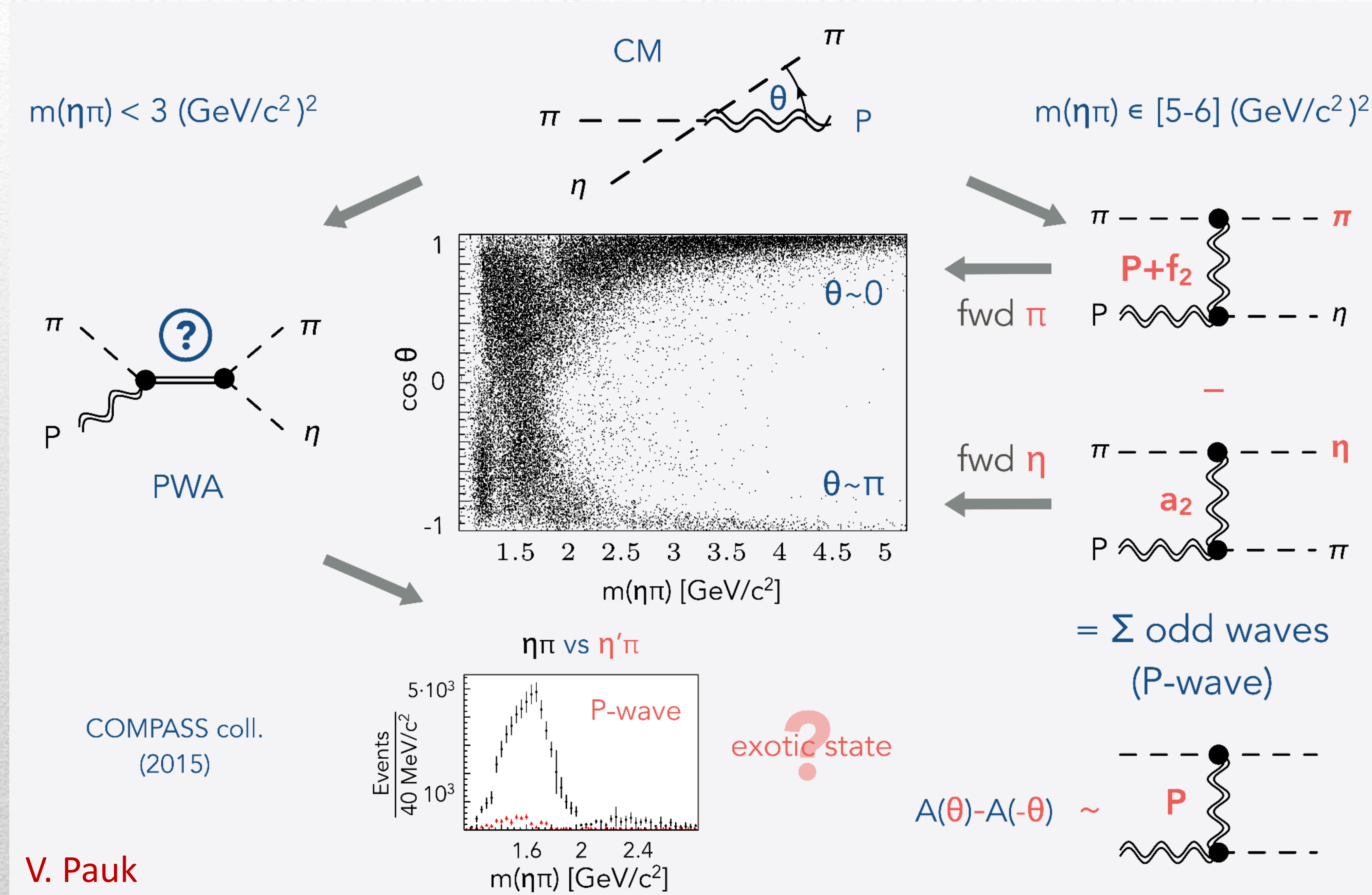
Unitarity

These are constraints the amplitudes have to satisfy, but do not fix the dynamics

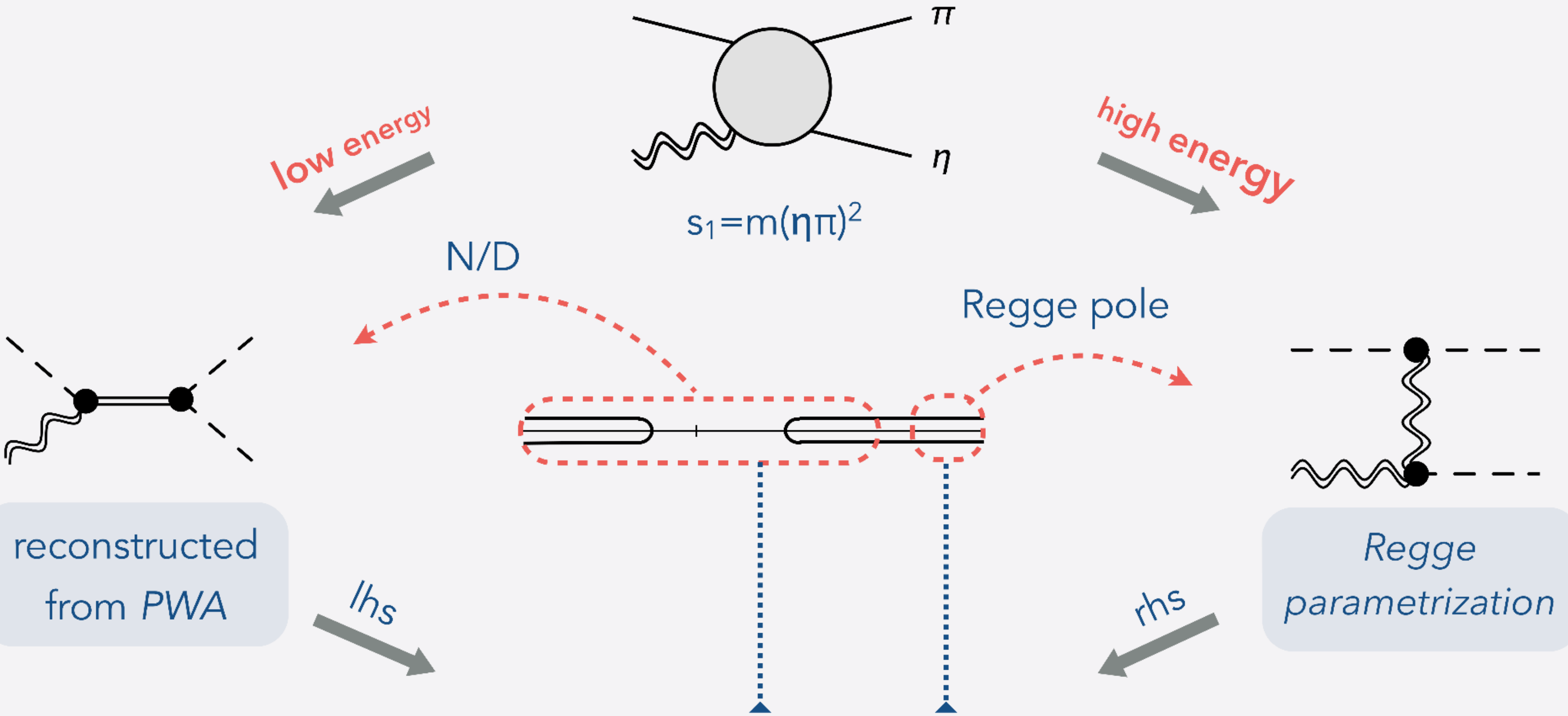
Resonances (QCD states) are poles in the unphysical Riemann sheets

At high energies, other constraints from Regge theory (exchanges of towers of particles of any spin)

$\eta\pi$ production at COMPASS



Finite energy sum rules



$$\int_0^N \mathrm{d}s\,\mathrm{Im}\,A(s) = N^{\alpha+1}V$$

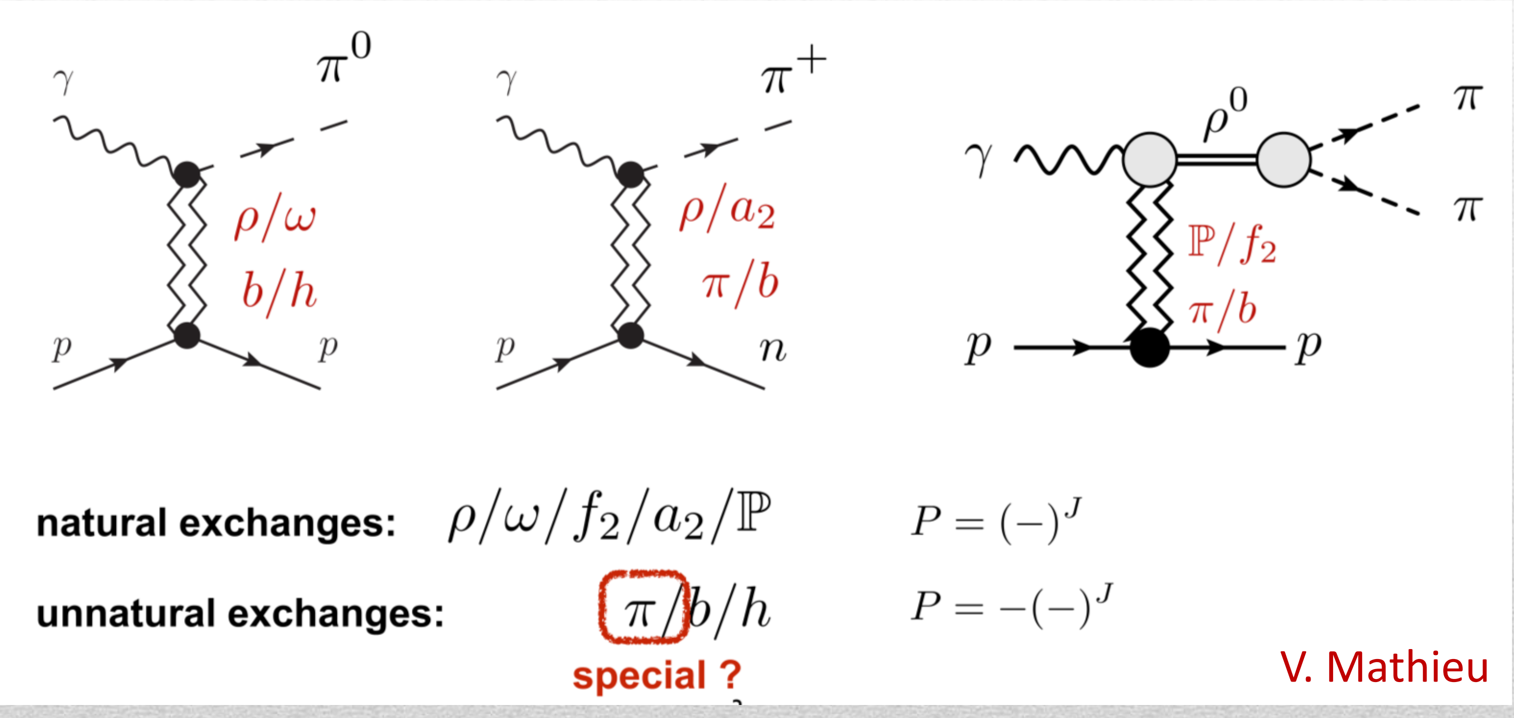
aim: *first systematic analysis*
of ***peripheral production*** *using* ***FESR***

V. Pauk

π, ρ photoproduction

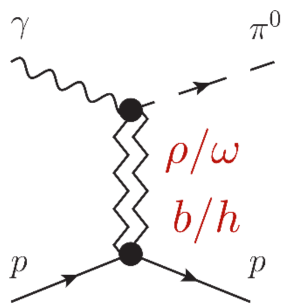
Test factorization on the simplest cases

1. Neutral pion photoproduction
2. Charged pion photoproduction
3. Rho meson photoproduction



$\gamma\, p \to \pi^0\, p$

Model based on factorization with parameters fitted

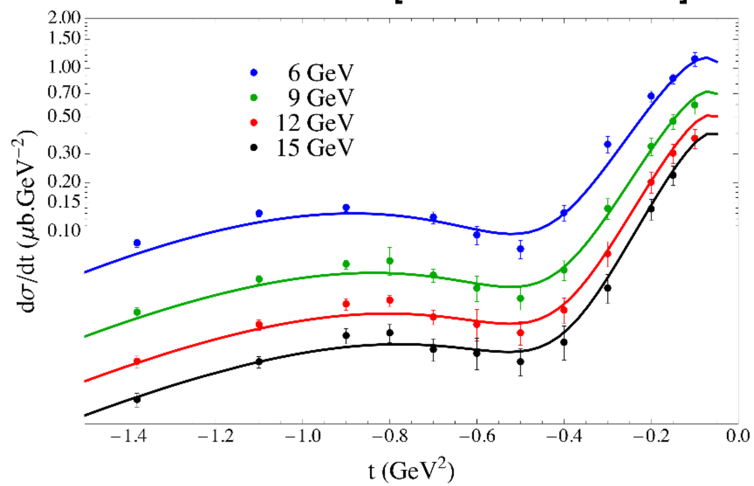


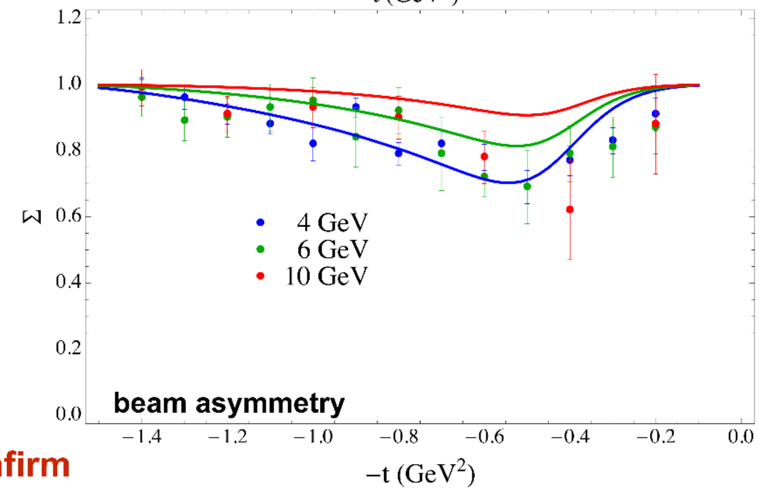
$$\Sigma = \frac{\sigma_\perp - \sigma_\parallel}{\sigma_\perp + \sigma_\parallel} = \frac{|\rho+\omega|^2 - |b+h|^2}{|\rho+\omega|^2 + |b+h|^2}$$

axial-vector exchanges strength decreases with energy

More precise data@JLAB could confirm

diff cross section [Anderson et al. 1971]



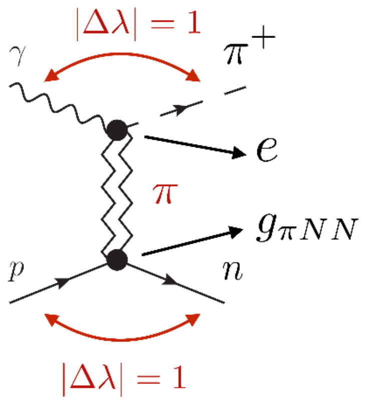


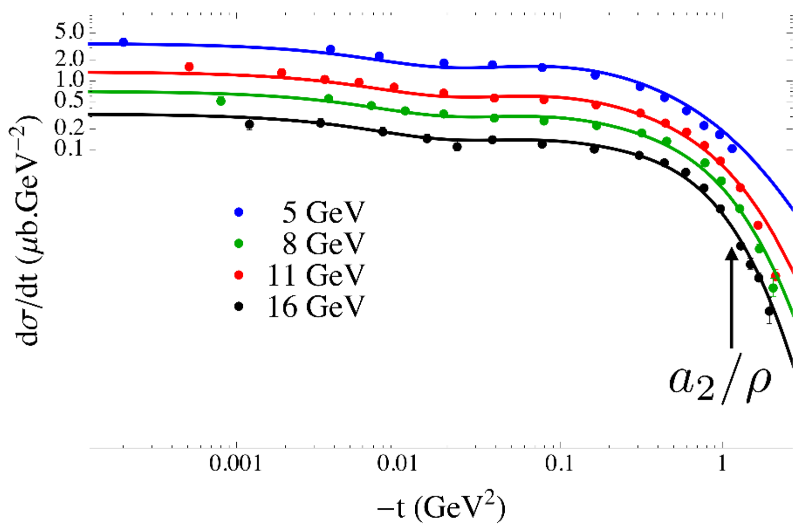
VM, Szczepaniak and Fox Phys. Rev. D. 92 074013

$\gamma\, p \to \pi^+\, n$

Pion dominate very small |t| :

[Boyarski et al. 1968]





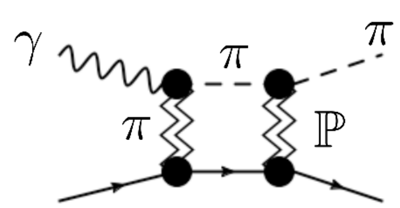
Factorization of Regge residues:
$(\lambda_\gamma, \lambda_\pi) = (1, 0)$ **and**

$$(\lambda_p, \lambda_n) = \left(-\frac{1}{2}, +\frac{1}{2}\right) \qquad A^{10}_{-\frac{1}{2}\,\frac{1}{2}} \propto \frac{-t}{m_\pi^2 - t}$$

$$(\lambda_p, \lambda_n) = \left(+\frac{1}{2}, -\frac{1}{2}\right) \qquad A^{10}_{\frac{1}{2}\,-\frac{1}{2}} \propto \frac{-t}{m_\pi^2 - t}$$

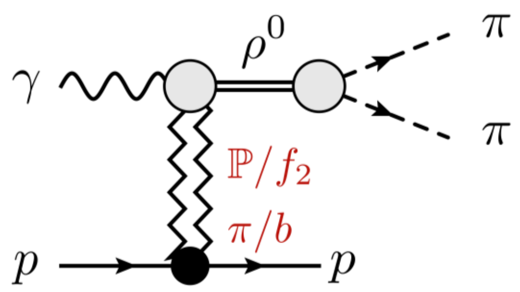
$$|(\lambda_\gamma - \lambda_p) - (\lambda_\pi - \lambda_{p'})| = 0$$

William's Poor man absorption: $\to \dfrac{-m_\pi^2}{m_\pi^2 - t}$



V. Mathieu

$\gamma\, p \to \rho^0\, p$



Use beam polarization to extract spin density matrix elements:

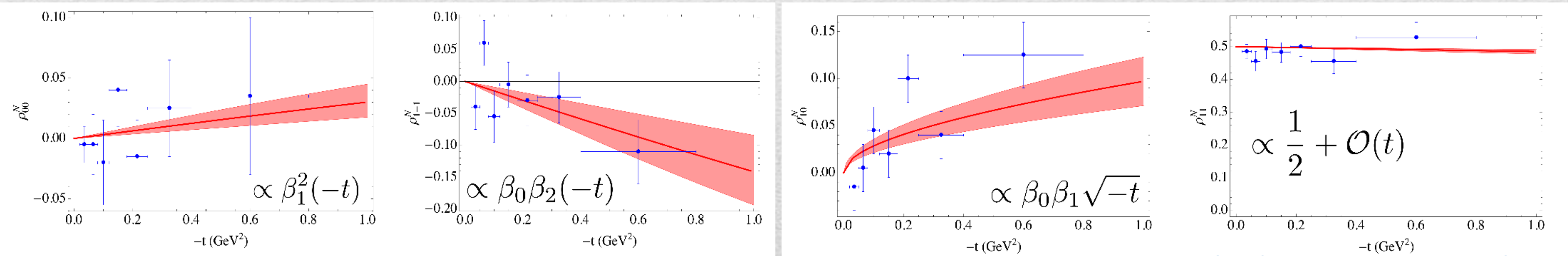
$$\rho^0_{MM'} = \frac{1}{N} \sum_{\lambda_\gamma \lambda_p \lambda_{p'}} A_{\lambda_\gamma \lambda_p \lambda_{p'}, M} A^*_{\lambda_\gamma \lambda_p \lambda_{p'}, M'}$$

$$\rho^1_{MM'} = \frac{1}{N} \sum_{\lambda_\gamma \lambda_p \lambda_{p'}} A_{\lambda_\gamma \lambda_p \lambda_{p'}, M} A^*_{-\lambda_\gamma \lambda_p \lambda_{p'}, M'}$$

$$N = \sum_\lambda |A_\lambda|^2$$

At leading s, one can separate natural and unnatural exchanges

Test factorization at top vertex: non-flip $\beta_0\left(\sqrt{-t}\right)^0$, single-flip $\beta_0\left(\sqrt{-t}\right)^0$, double-flip $\beta_2\left(\sqrt{-t}\right)^2$

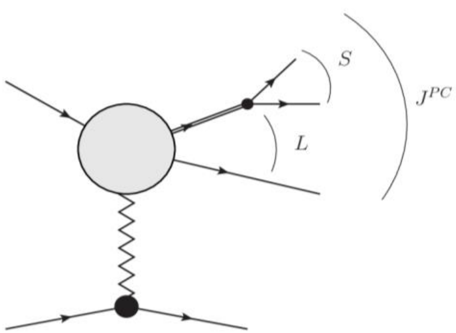


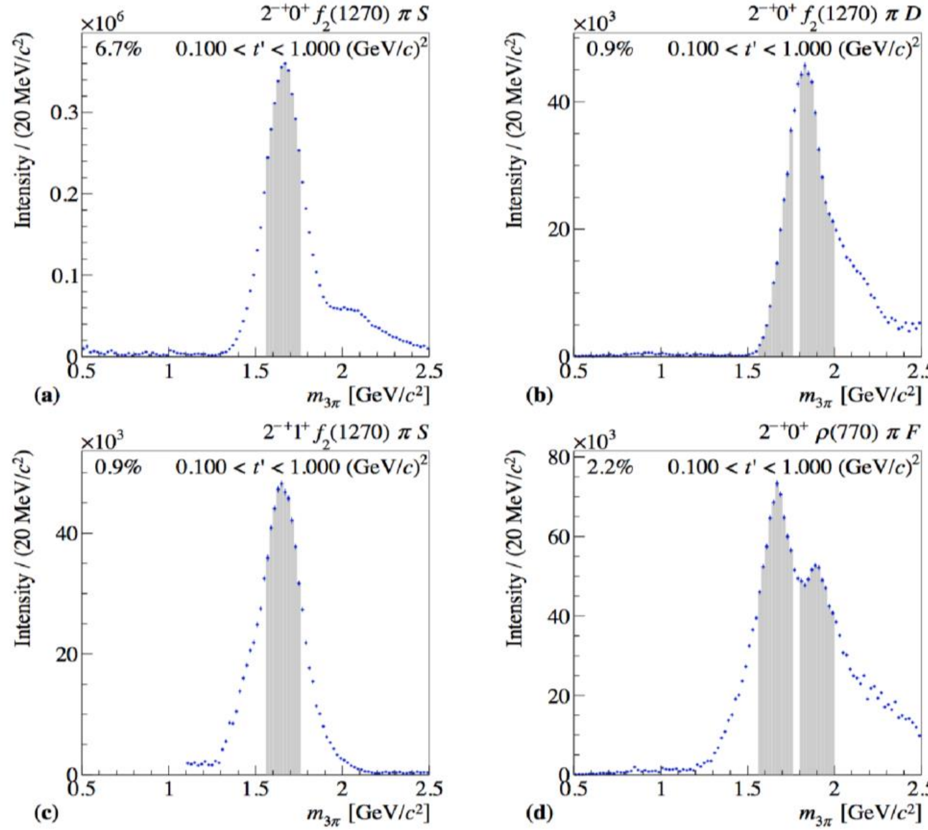
Fit gives $\beta_0 : \beta_1 : \beta_2 = 1.00 : 0.14 : -0.09$, which agrees with the expected trend

V. Mathieu

PWA of 3π sytem

- Develop method of analysis satisfying S-matrix principles, study J^{PC} resonances in 3π
- In this presentation, we focus on 2^{-+},
  - long standing puzzle about $\pi_2(1670)$–$\pi_2(1880)$ interplay,
  - 17 waves out of 88 have $J^{PC} = 2^{-+}$,





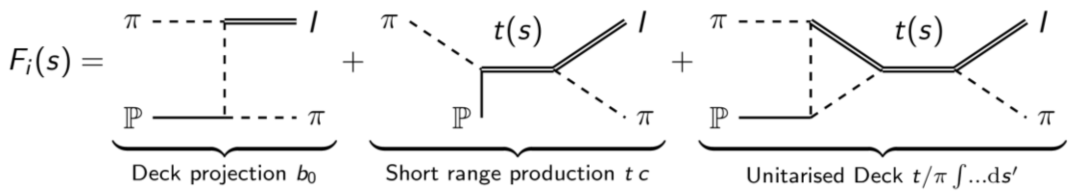
[C. Adolph *et al.* [COMPASS Collaboration], arXiv:1509.00992]

A. Jackura, M. Mikhasenko

PWA of 3π sytem

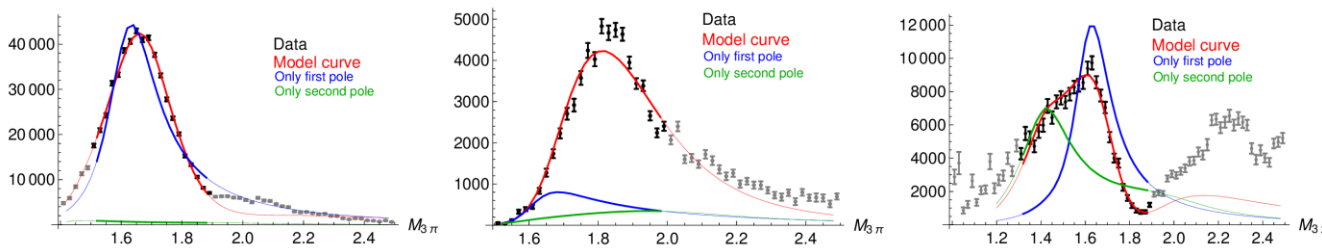
Now use unitarized Deck amplitude developed for this analysis

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



Data: three main waves at low $|t'|$ ($0.1\,\mathrm{GeV}^2$-$0.113\mathrm{GeV}^2$):

$$2^{-+}0^+ \, f_2\pi \, S, \qquad 2^{-+}0^+ \, f_2\pi \, D, \qquad 2^{-+}0^+ \, (\pi\pi)_s \pi D.$$

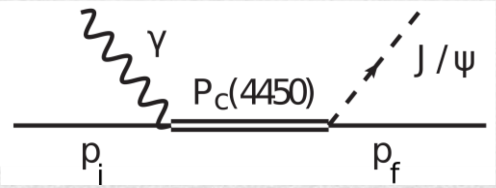


- K-matrix assumes elasticity, so simultaneous fit of all decay channels are needed (all 3π waves),
- data for 11 $|t'|$ intervals are available. $|t'|$-dependence of non-resonance component is fixed by "Deck" model.

Pentaquark photoproduction

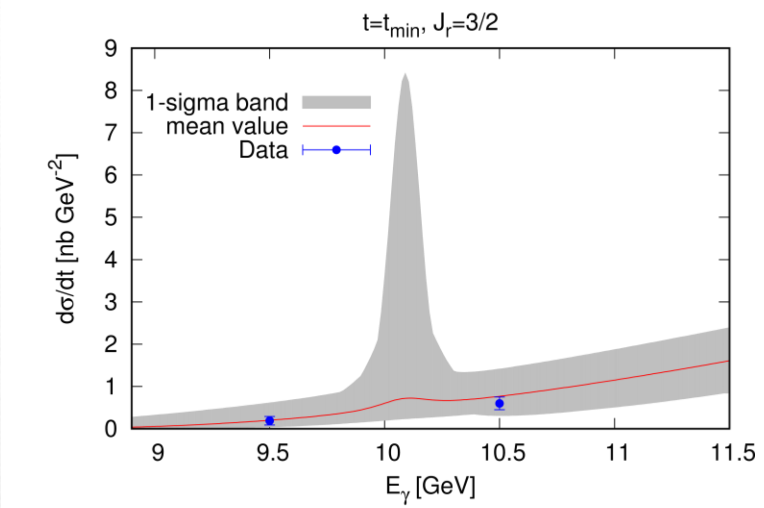
We propose to search the $P_c(4450)$ state in photoproduction

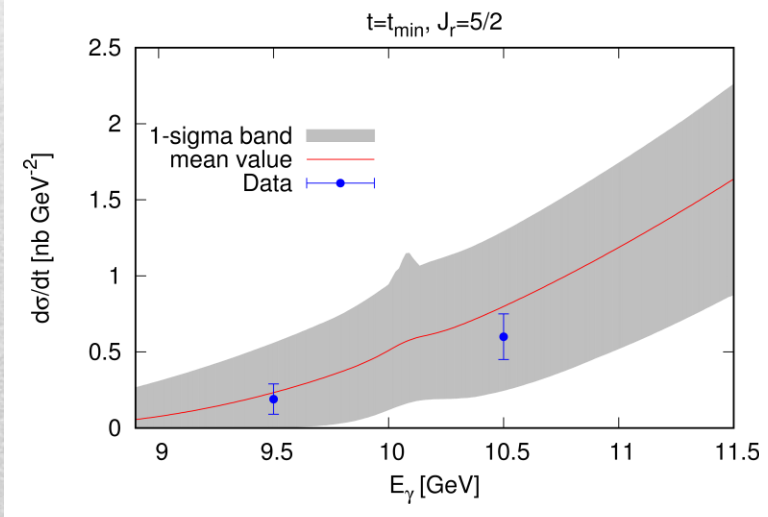
We use the (few) existing data and VMD + pomeron inspired bkg to estimate the cross section



$$J^P = (3/2)^-$$

σ_s (MeV)	0	60	120
A	$0.156^{+0.029}_{-0.020}$	$0.157^{+0.039}_{-0.021}$	$0.157^{+0.037}_{-0.022}$
α_0	$1.151^{+0.018}_{-0.020}$	$1.150^{+0.018}_{-0.026}$	$1.150^{+0.015}_{-0.023}$
α' (GeV^{-2})	$0.112^{+0.033}_{-0.054}$	$0.111^{+0.037}_{-0.064}$	$0.111^{+0.038}_{-0.054}$
s_t (GeV^2)	$16.8^{+1.7}_{-0.9}$	$16.9^{+2.0}_{-1.6}$	$16.9^{+2.0}_{-1.1}$
b_0 (GeV^{-2})	$1.01^{+0.47}_{-0.29}$	$1.02^{+0.61}_{-0.32}$	$1.03^{+0.49}_{-0.31}$
$\mathcal{B}_{\psi p}$	$\leq 29\,\%$	$\leq 30\,\%$	$\leq 22\,\%$

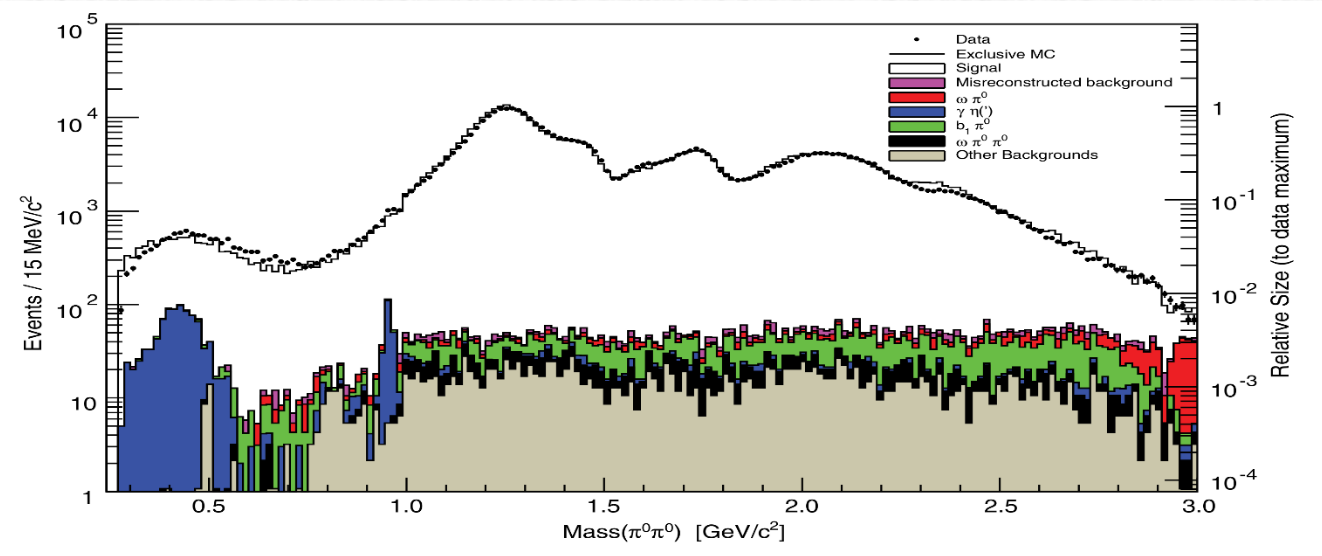




A. Blin

$J/\psi \to \gamma\, \pi^0\pi^0$

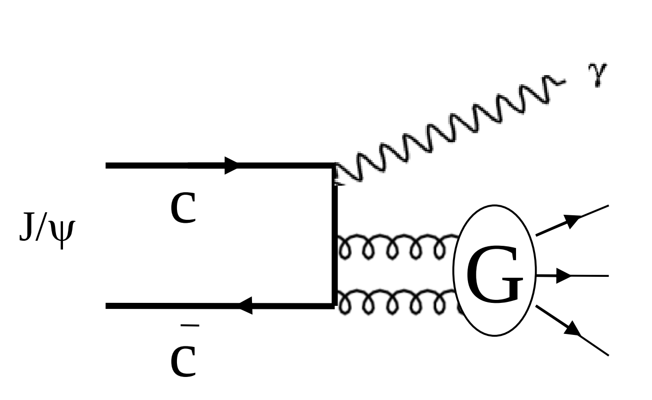
BESIII published in 2015 a partial wave analysis of $J/\psi \to \gamma\, \pi^0\pi^0$



BESIII
PRD92, 052003

Bose symmetry and charge conjugation force the dipion to have $J^{PC}\ I^G = (\text{even})^{++}\ 0^+$

This is a gluon-rich process, expected to be one of the golden channels for the search of the scalar glueball

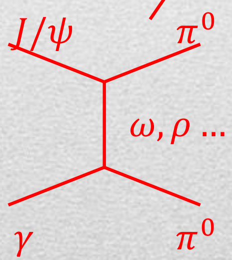


$J/\psi \to \gamma\, \pi^0\pi^0$

We start approximating the problem to 1 channel, i.e. neglecting inelasticities.
Unitarity and dispersion relations allow us to write the solution in terms of the Omnès function

$$\mathrm{Disc}_R\, f_\mu^J = \rho(s) f_\mu^J A_{\pi\pi}^{J*} = f_\mu^J e^{-i\delta_J} \sin\delta_J$$

$$f_\mu^J(s) = v_\mu^J(s) + \Omega(s)\left(P_k(s) + \frac{1}{\pi}\int_{4m_\pi^2}^\infty ds' \frac{v_\mu^J(s') e^{i\delta_J(s')} \sin\delta_J(s') \Omega^{-1}(s')}{(s')^k (s'-s)}\right)$$



Depends on the $\pi\pi$ scattering phase, parametrized with K matrix

$$K_\pi = \frac{m_\pi^2 - 2s}{2 f_\pi^2}$$

$$K_R = \sum_i \frac{g_i}{M_i^2 - s} + \sum_j \gamma_j s^j$$

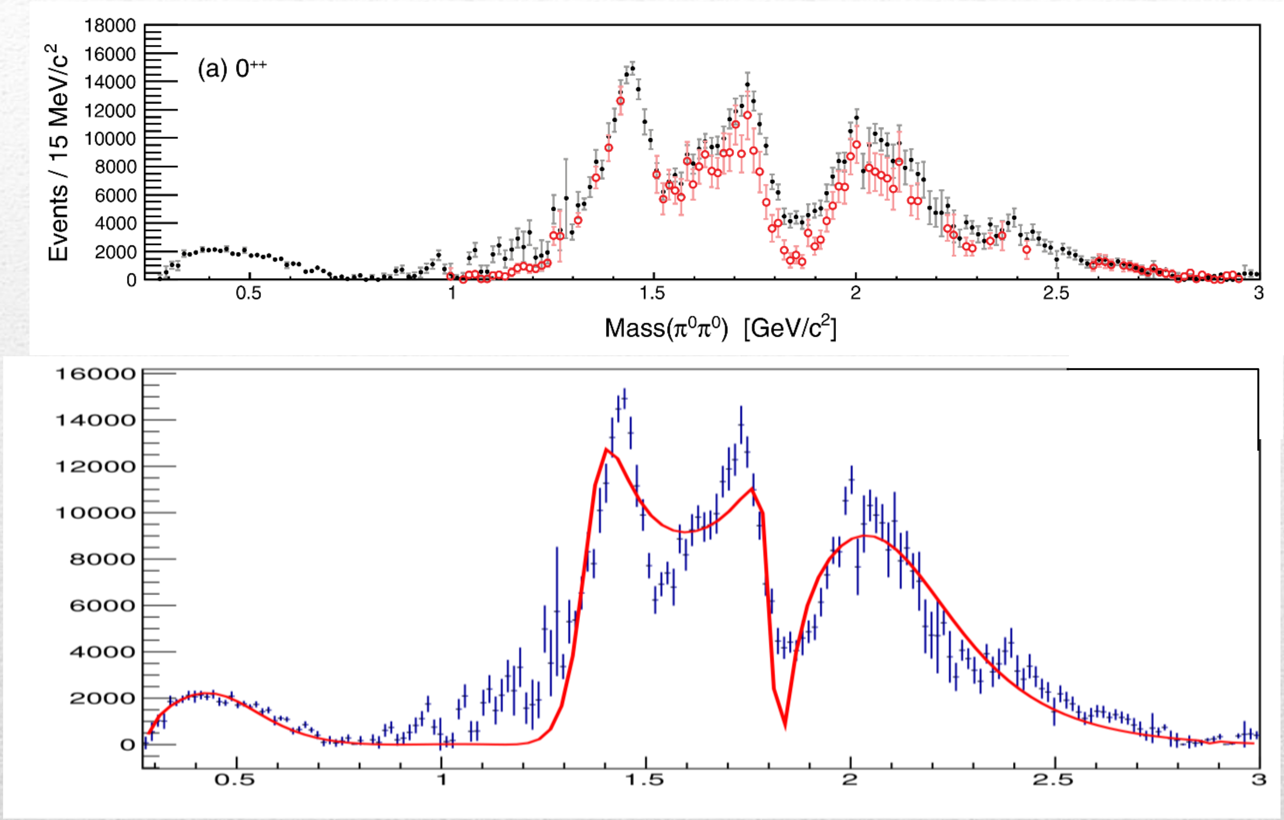
A. Pilloni

Adler zero
describes the σ region

K-matrix poles

Background terms
(effective LHC)

$J/\psi \to \gamma\, \pi^0\pi^0$: preliminary fit



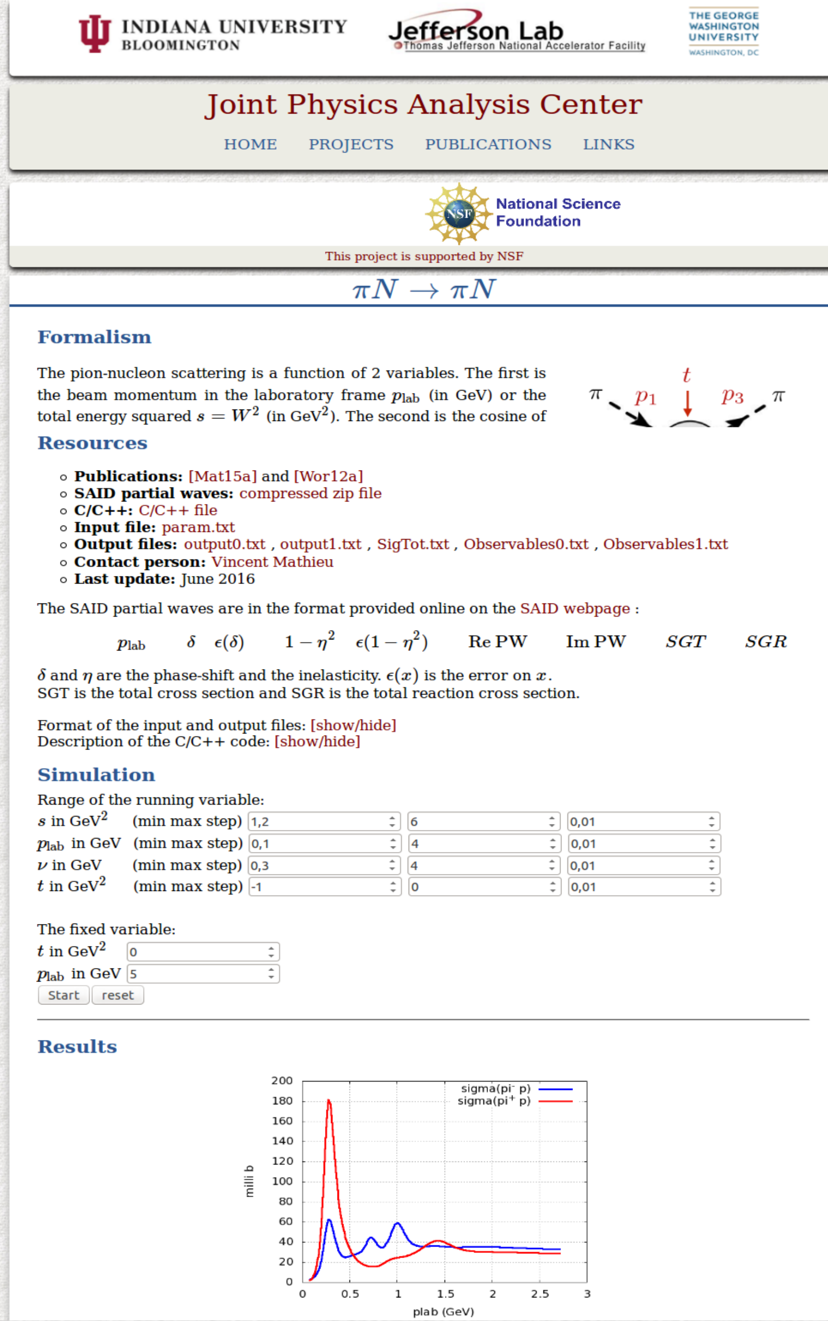
The fit qualitatively reproduces the σ region and the higher resonances, but as expected fails to describe the $f_0(980)$ region: an effective $K\bar{K}$ threshold has to be included

A. Pilloni

Interactive tools

- Completed projects are fully documented on interactive portals
- These include description on physics, conventions, formalism, etc.
- The web pages contain source codes with detailed explanation how to use them. Users can run codes online, change parameters, display results.

http://www.indiana.edu/~jpac/



Overview

$K\ N \rightarrow\ K\ N$	C. Fernandez-Ramirez *et al.*,	PRD93, 034029
$\pi\ N \rightarrow \pi\ N$	V. Mathieu *et al.*,	PRD92, 074004
$\gamma\ p \rightarrow\ \pi^0\ p$	V. Mathieu *et al.*,	PRD92, 074013
$\eta \rightarrow \pi^+\ \pi^-\ \pi^0$	P. Guo *et al.*,	PRD92, 054016
$\omega, \phi \rightarrow \pi^+\ \pi^-\ \pi^0$	I. Danilkin *et al.*,	PRD91, 094029
$\gamma\ p \rightarrow\ K^+\ K^-\ p$	M. Shi *et al.*,	PRD91, 034007

Thank you!

BACKUP

Joint Physics Analysis Center (JPAC)

JPAC members

Mike Pennington (JLab)
Adam Szczepaniak (IU/JLab)
Tim Londergan (IU)
Geoffrey Fox (IU)
Emilie Passemar (IU/JLab)
Peng Guo (Cal. St.)
Cesar Fernandez-Ramirez (JLab)
Ron Workman (GWU)
Michael Döring (GWU)

Vladyslav Pauk (JLab)
Alessandro Pilloni (JLab)
Igor Danilkin (Mainz)
Lingyun Dai (Bonn)
Meng Shi (Beijing)
Astrid Blin (Valencia)
Andrew Jackura (IU)
Vincent Mathieu (IU)
…

CLAS collaboration
Diane Schott (GWU/JLab)
Viktor Mokeev (JLab)
HASPECT:
Marco Battaglieri (Genova)
Derek Glazier (Glasgow)
…

GlueX collaboration
Matthew Shepherd (IU)
Justin Stevens (JLab)
…

COMPASS collaboration
Mikhail Mikhasenko (Bonn)
Fabian Krinner (TUM)
Boris Grube (TUM)
…