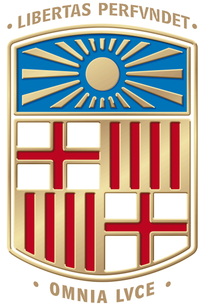
STRONG-2020 Task 3.1

Meson Spectroscopy Analysis of New and Exotic States: Search for and study of light exotic mesons, charmonium and strangeonium

Vincent MATHIEU

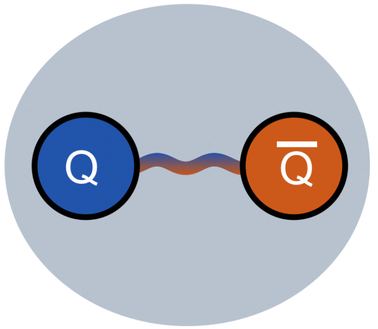
Complutense Universidad de Madrid
Universidad de Barcelona

Valencia - TAHSP - December 2020



Light Exotic Mesons, Charmonium and Strangeonium

Ordinary mesons

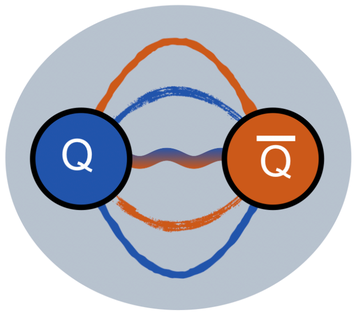


"Exotic" in the quark model sense
meson different from $q\bar{q}$

identification through quantum numbers,
decay modes, and/or analysis

Tetraquarks

Hybrid mesons



Discovery Exotic Mesons

Design and build detectors
Collect data
Build observables
Fit data
Extract pole position,
…

Experiments
Tools

Interpretation

Theory

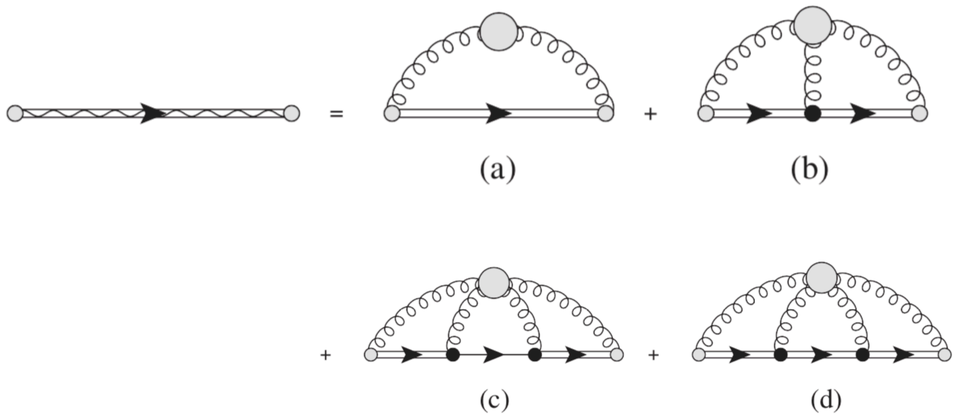
Lattice QCD,
Constituent Models,
Effective Field Theories,
…

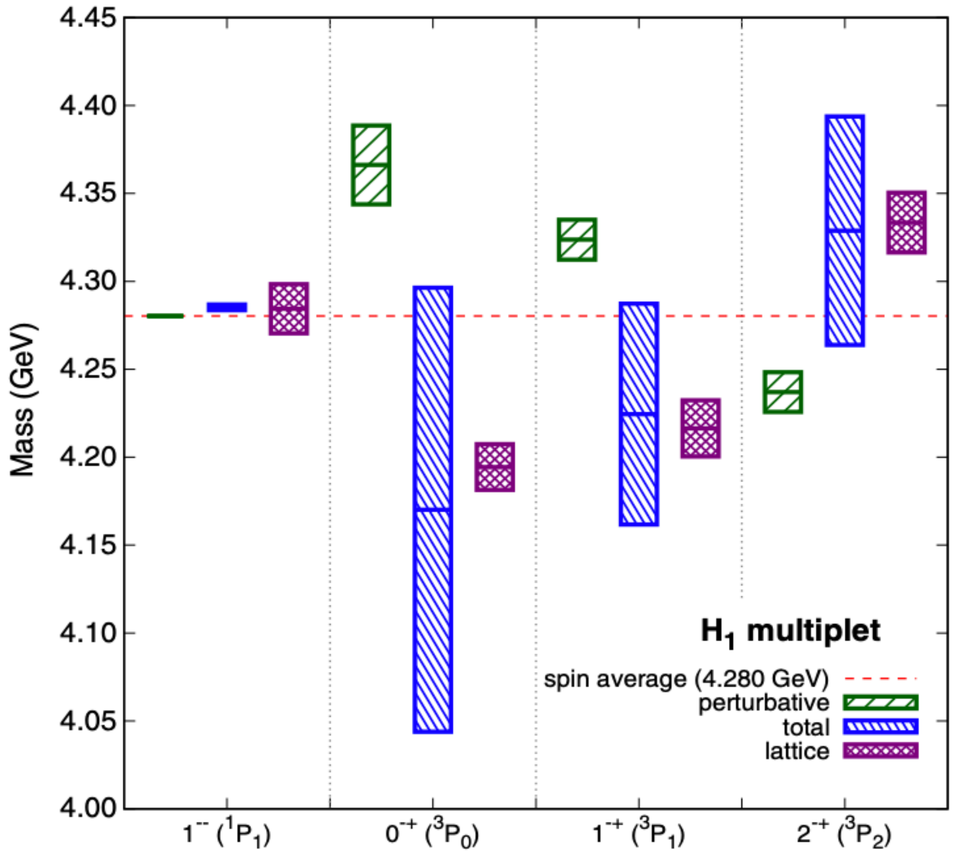
$c\bar{c}g$ from pNRQCD

Coordinator: Nora Brambilla (talk at 16:45 and collaborator Hee Sok Chung at 17:45)

Brambilla, Lai, Segovia, Castella and Vairo
PRD101 (2020) 054040

Spectra of exotic charmonium derived from pNRQCD with spin-depend force included





$q\bar{q}g$ from EFT

Coordinator: Francesco Giacosa (talk tomorrow at 14:45)

Eshraim, Fischer, Giacosa and Parganlija
EPJ Plus 135 (2020) 945

Linear Sigma Model
extended with hybrid mesons

$\pi_1 \to b_1\pi, \ldots$

$$\mathcal{L}_{eLSM,1}^{\text{hybrid-linear}} = i2\lambda_1^{hyb} G \left\{ \text{Tr}\left[\Pi_\mu^{hyb}\left[P, B^\mu\right]\right] + \text{Tr}\left[\Pi_\mu^{hyb}\left[V_E^\mu, S\right]\right]\right\} + 2\lambda_1^{hyb} G \left\{ \text{Tr}\left[B_\mu^{hyb}\left\{P, V_E^\mu\right\}\right] + \text{Tr}\left[B_\mu^{hyb}\left\{B^\mu, S\right\}\right]\right\}.$$

Resonance	Mass [MeV]
π_1^{hyb}	1660 [**input** using $\pi_1(1600)$ [9]]
$\eta_{1,N}^{hyb}$	1660
$\eta_{1,S}^{hyb}$	1751
K_1^{hyb}	1707
b_1^{hyb}	2000 [**input** set as an estimate]
$h_{1N,B}^{hyb}$	2000
$K_{1,B}^{hyb}$	2063
$h_{1S,B}^{hyb}$	2126

Ratio	Value
$\Gamma_{\pi_1^{hyb}\to\pi\eta'}/\Gamma_{\pi_1^{hyb}\to\pi\eta}$	12.7
$\Gamma_{K_1^{hyb}\to K\eta}/\Gamma_{\pi_1^{hyb}\to\pi\eta}$	0.69
$\Gamma_{K_1^{hyb}\to K\eta'}/\Gamma_{\pi_1^{hyb}\to\pi\eta}$	5.3
$\Gamma_{\eta_{1,N}^{hyb}\to\eta\eta'}/\Gamma_{\pi_1^{hyb}\to\pi\eta}$	2.2
$\Gamma_{\eta_{1,S}^{hyb}\to\eta\eta'}/\Gamma_{\pi_1^{hyb}\to\pi\eta}$	1.57

Ratio	Value
$\Gamma_{K_1^{hyb}\to Kh_1(1170)}/\Gamma_{\pi_1^{hyb}\to\pi b_1}$	0.050
$\Gamma_{b_1^{hyb}\to\pi\omega(1650)}/\Gamma_{\pi_1^{hyb}\to\pi b_1}$	0.065
$\Gamma_{K_{1B}^{hyb}\to\pi K^*(1680)}/\Gamma_{\pi_1^{hyb}\to\pi b_1}$	0.19
$\Gamma_{h_{1,N}^{hyb}\to\pi\rho(1700)}/\Gamma_{\pi_1^{hyb}\to\pi b_1}$	0.16

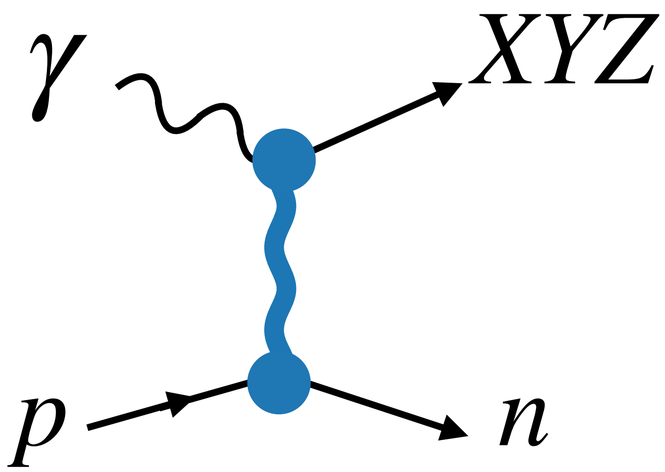
Estimation of XYZ Cross Sections @EIC

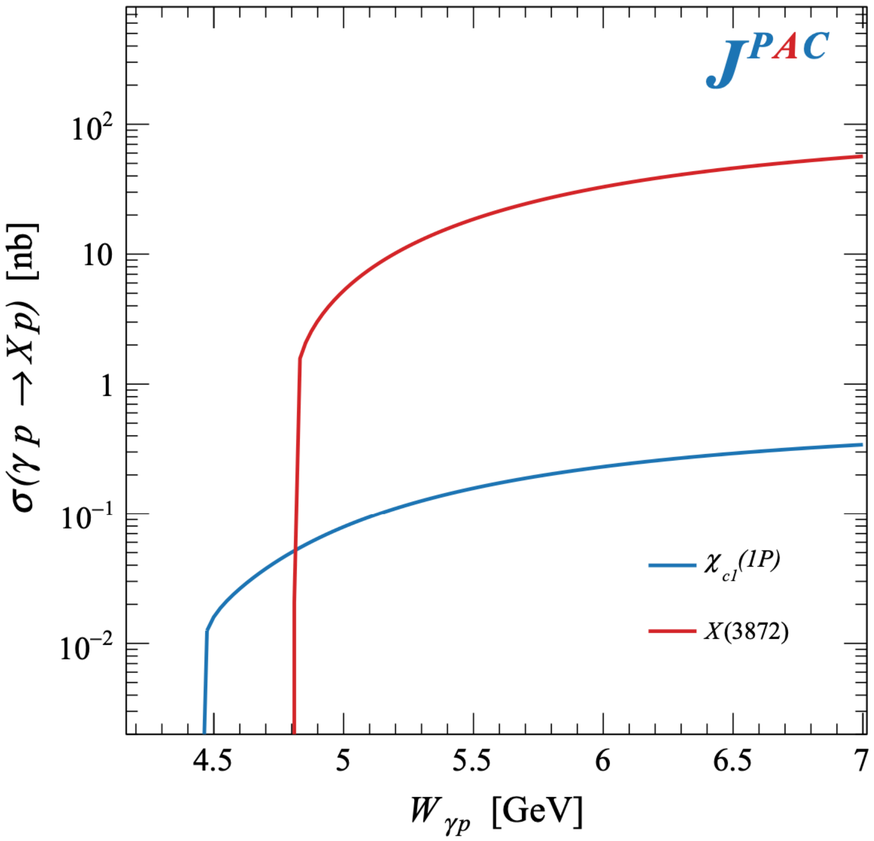
JPAC collaboration

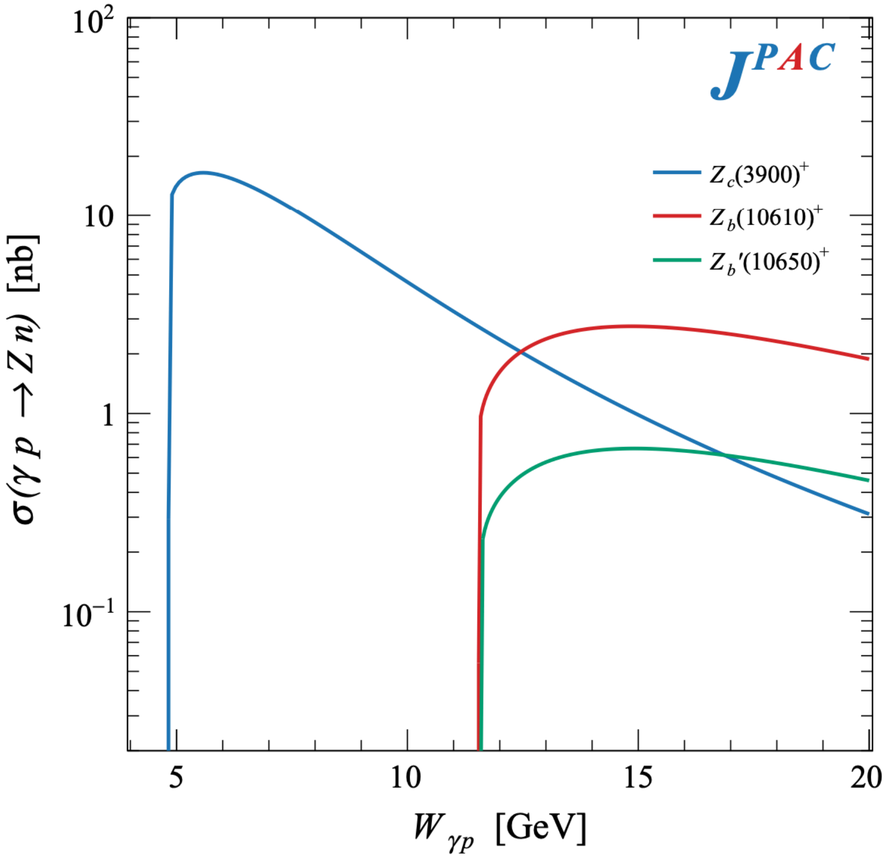
Albaladejo, Hiller-Blin, Pilloni, Winney, Fernández-Ramírez, VM and Szczepaniak
PRD102 (2020) 114010

Cross sections prediction for

$$X(3872), X(8900), Y(4260)$$
$$Z_c(3900)^+, Z_b(10610)^+, Z_b(10650)^+$$







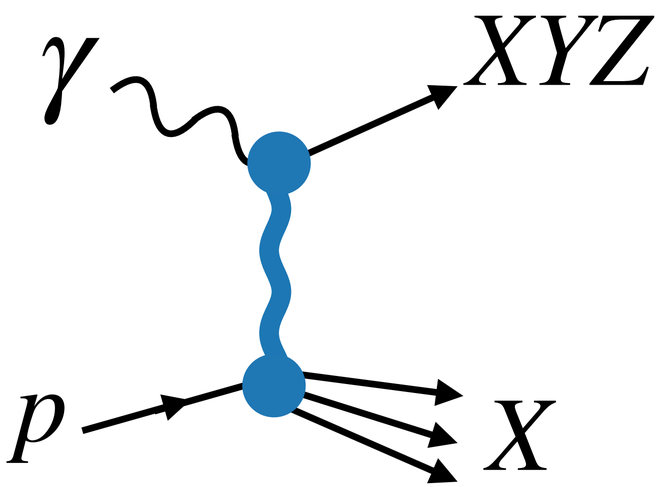
Estimation of XYZ Cross Sections @EIC

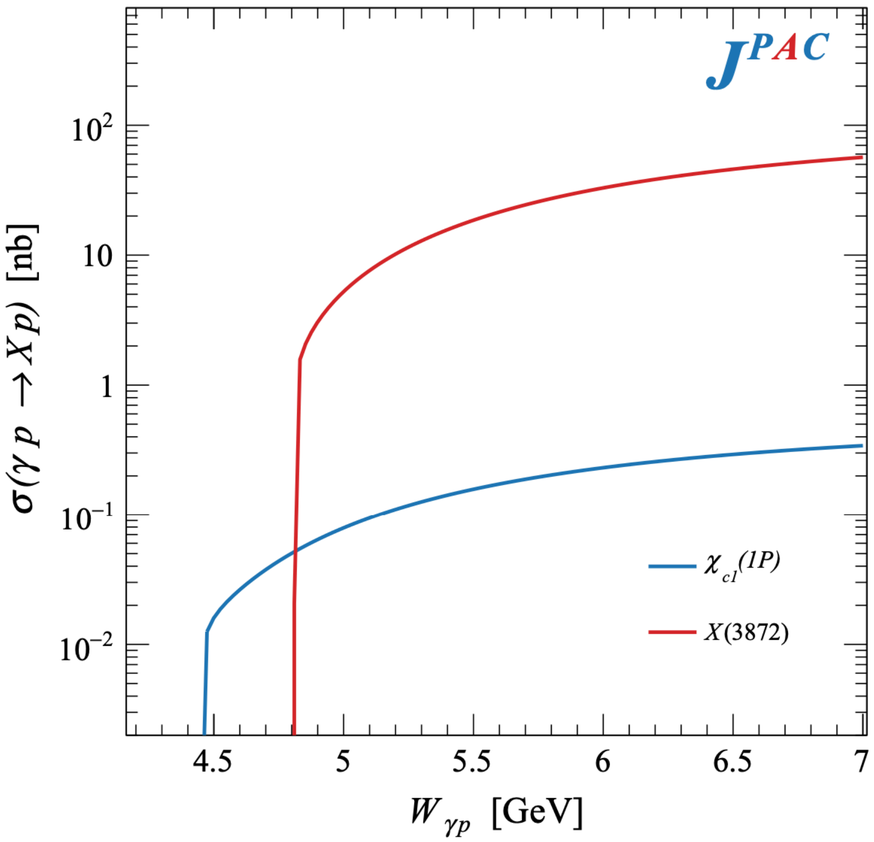
JPAC collaboration

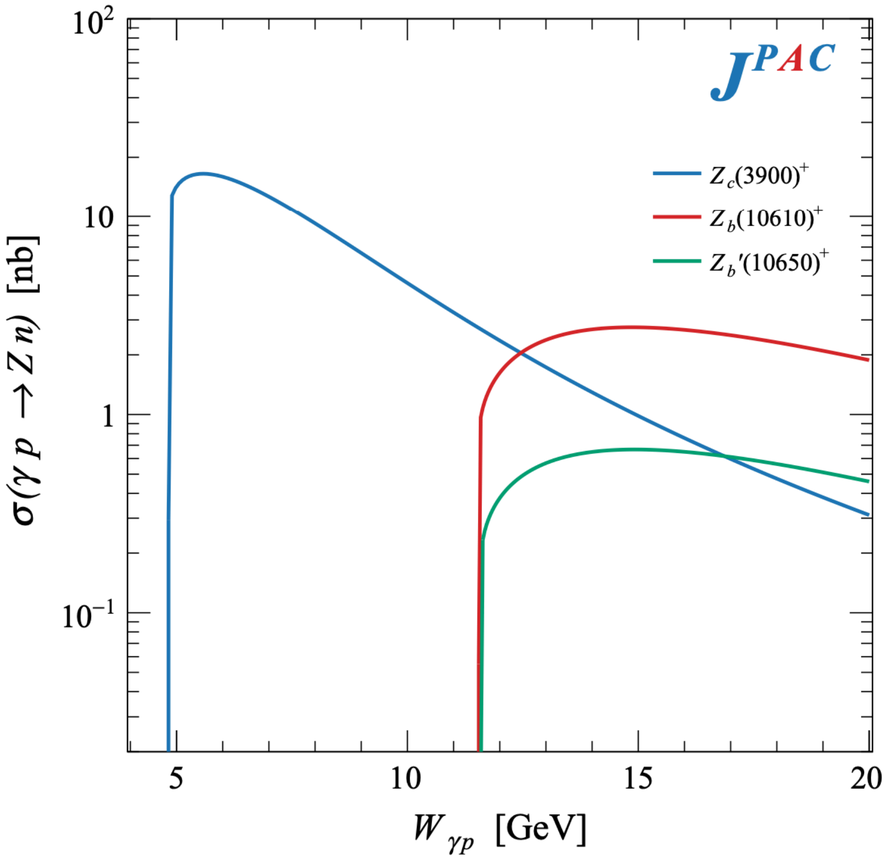
Albaladejo, Hiller-Blin, Pilloni, Winney, Fernández-Ramírez, VM and Szczepaniak
PRD102 (2020) 114010

Cross sections prediction for

$$X(3872), X(8900), Y(4260)$$
$$Z_c(3900)^+, Z_b(10610)^+, Z_b(10650)^+$$



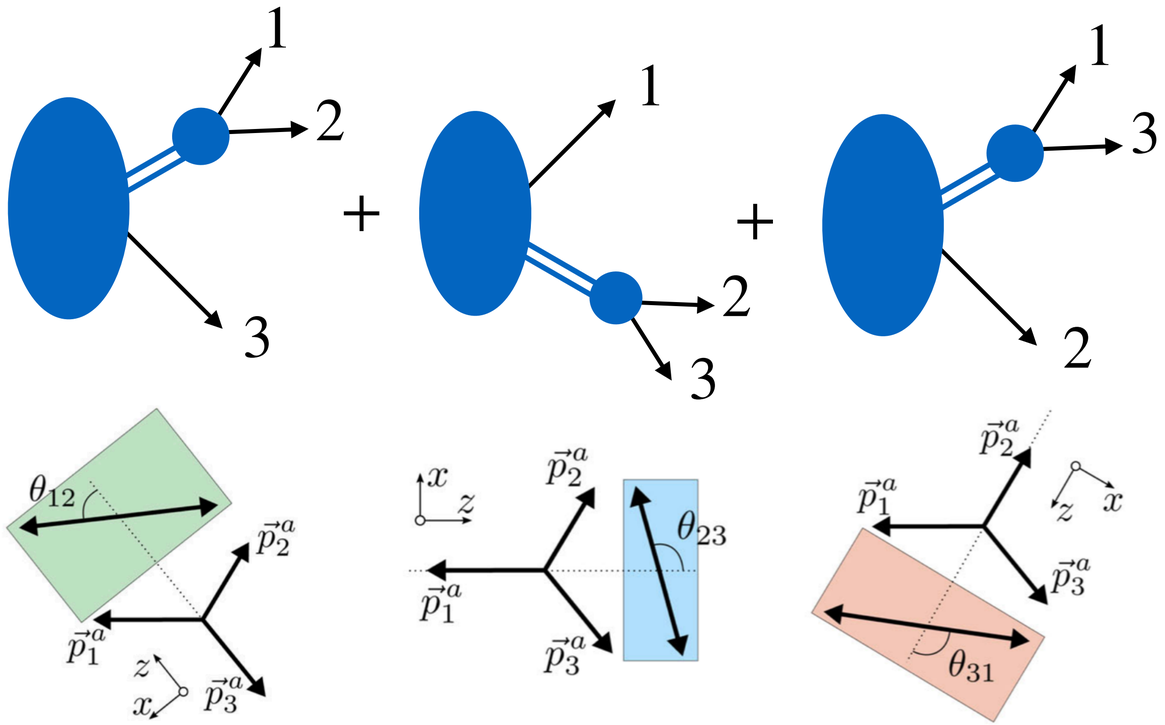




Formalism for Any Three-Body Decays

JPAC collaboration

Mikhasenko, Albaladejo, Bibrzycki, Fernández-Ramírez, VM, Mitchell, Papagallo, Pilloni, Winney, Skwarnicki, and Szczepaniak,
PRD101 (2020) 034033



Isobar parametrised in 2-body frame
need to be boosted in the 3-body frame

All kinematical functions coded and available:

http://cgl.soic.indiana.edu/jpac/DalitzPlot.php

Applied to: $\Lambda_c^+ \to pK^-\pi^+$

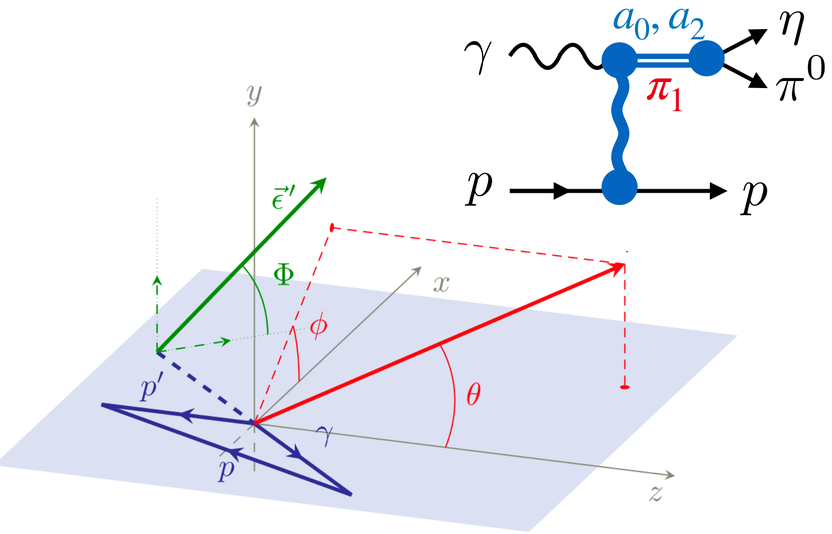
$\bar{B}^0 \to \psi K^-\pi^+$

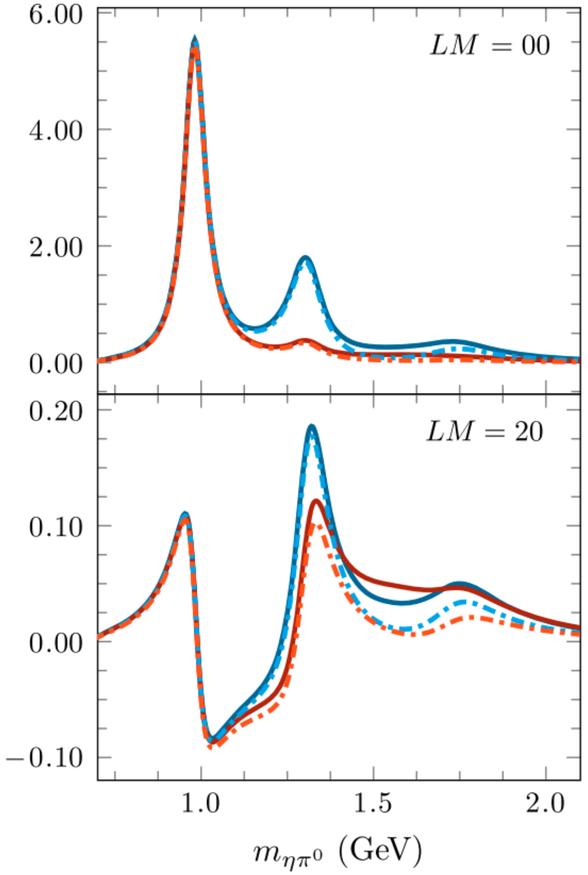
$\Lambda_b^0 \to pK^- J/\psi$

Moments of 2 Mesons Photoproduction

JPAC collaboration

VM, Albaladejo, Fernández-Ramírez, Jackura, Mikhasenko, Pilloni and Szczepaniak, PRD100 (2019) 054017





Formula to extract moments from angular distribution and their relation to partial waves

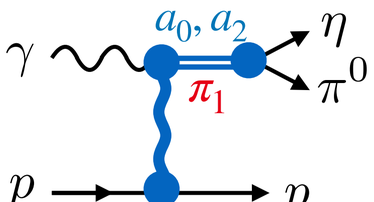
http://cgl.soic.indiana.edu/jpac/EtaPi_moments.php

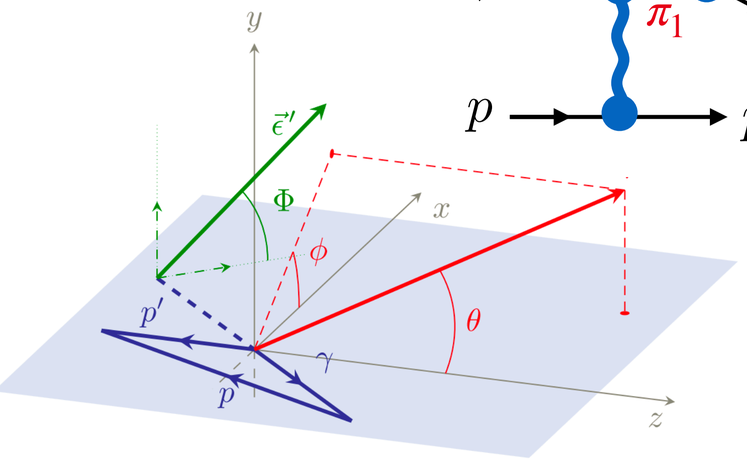
Implemented in GlueX analyses $\pi\eta, \pi\pi, \eta\eta$

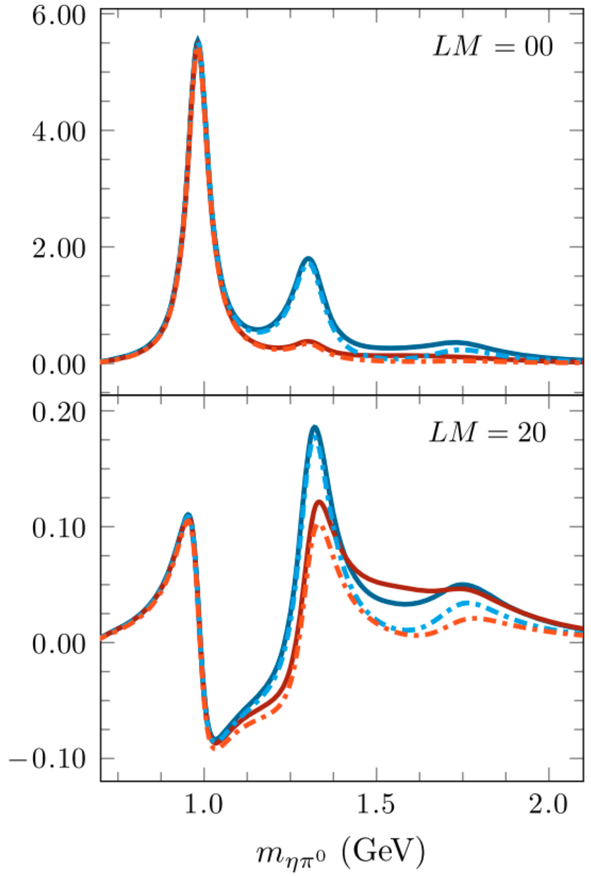
Moments of 2 Mesons Photoproduction

JPAC collaboration

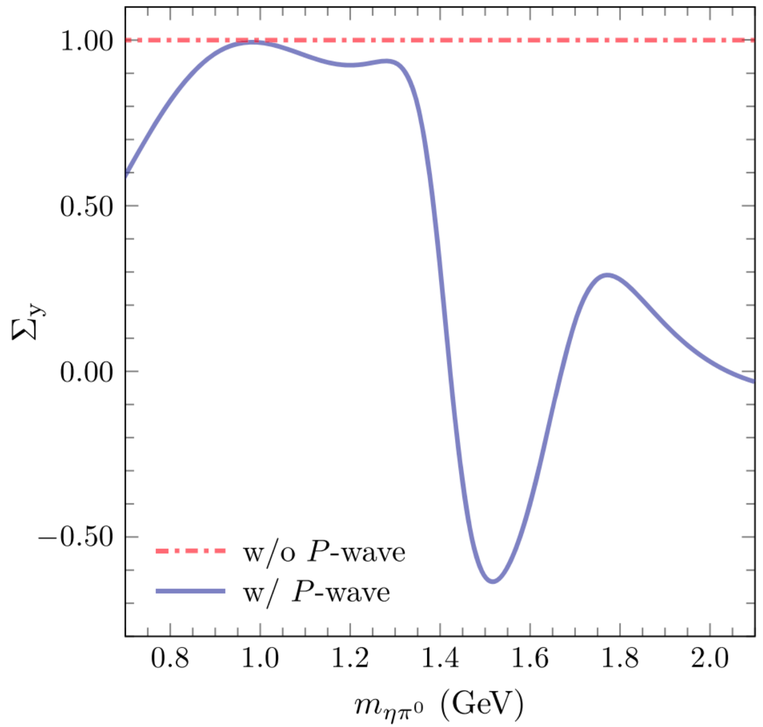
VM, Albaladejo, Fernández-Ramírez, Jackura, Mikhasenko, Pilloni and Szczepaniak, PRD100 (2019) 054017







New observable sensitive to exotic waves

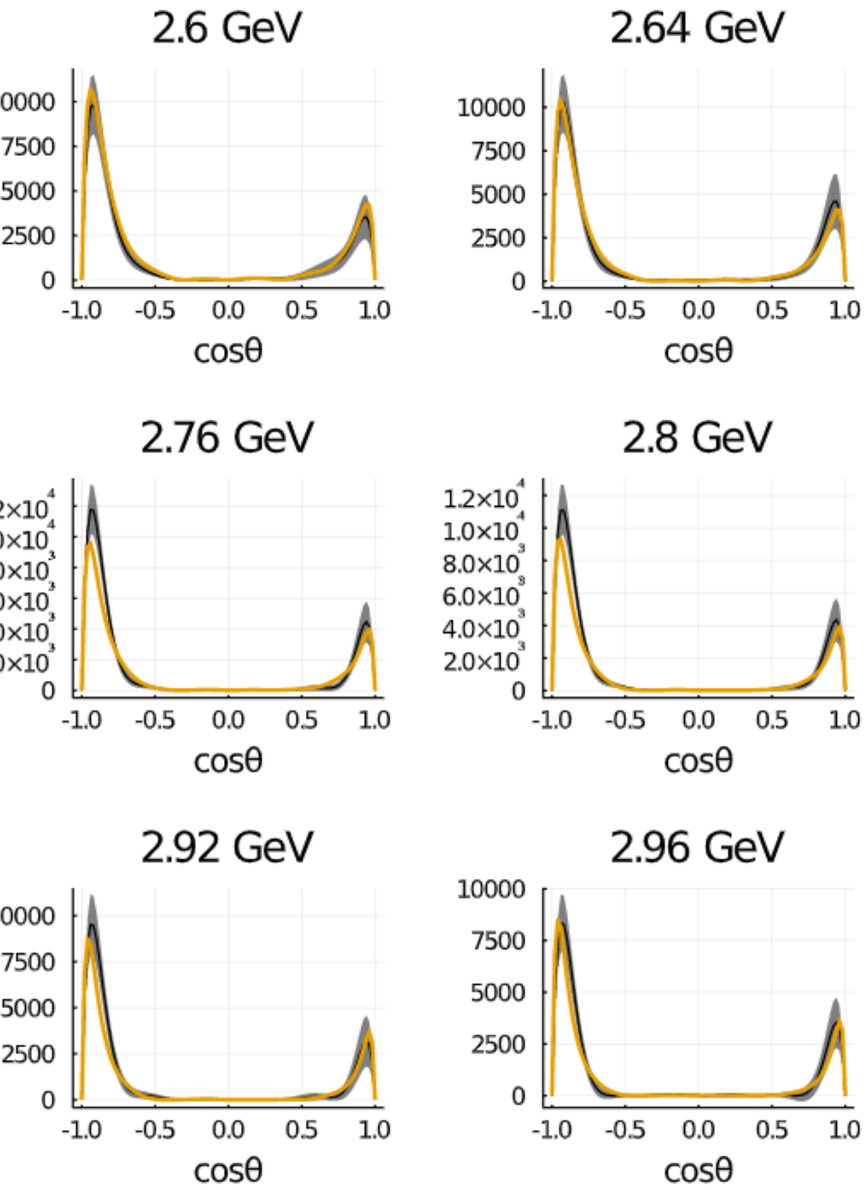


Formula to extract moments from angular distribution and their relation to partial waves

http://cgl.soic.indiana.edu/jpac/EtaPi_moments.php

Implemented in GlueX analyses $\pi\eta, \pi\pi, \eta\eta$

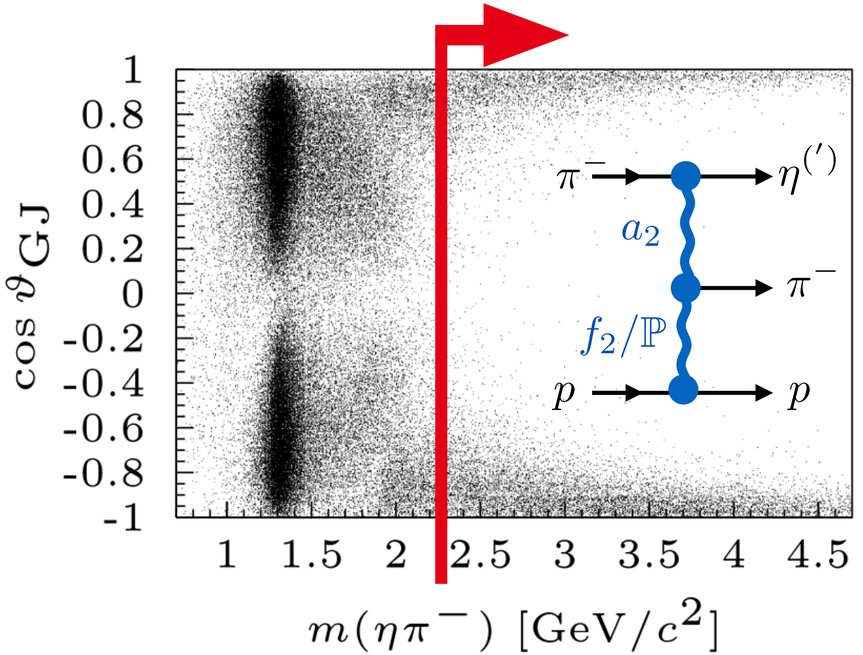
Double Regge Phenomenology



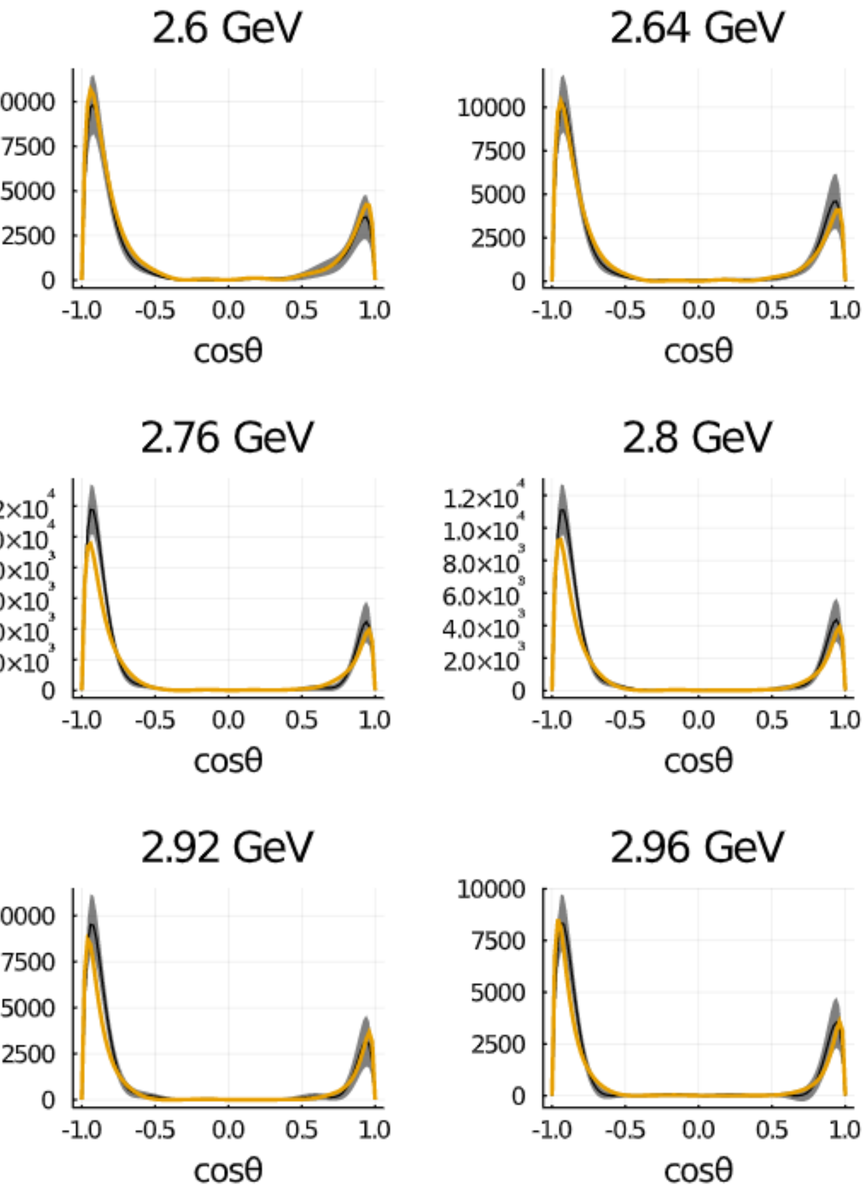
JPAC collaboration

Bibrzycki, Fernández-Ramírez, Mikhasenko, VM et al
work in progress

Fit COMPASS data with double Regge amplitudes



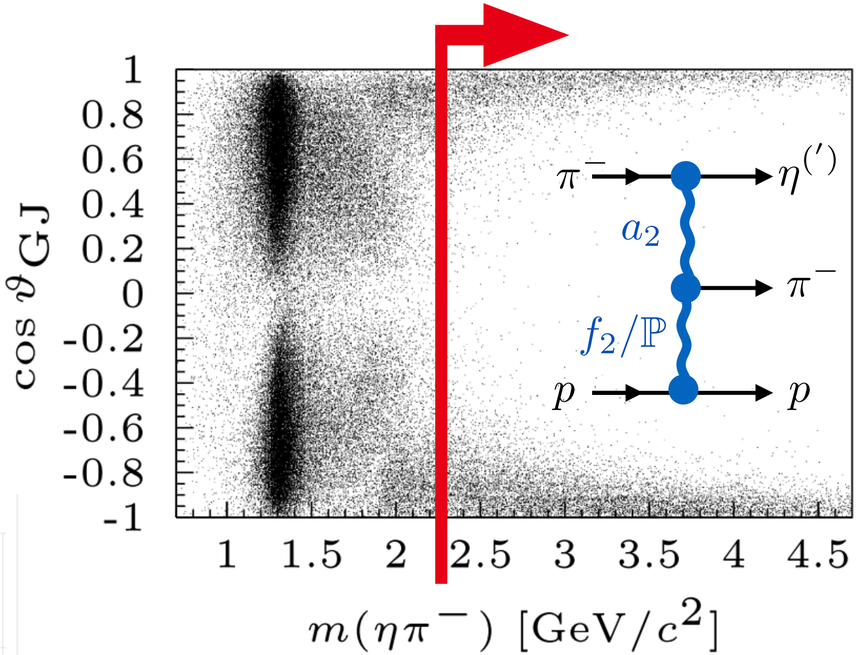
Double Regge Phenomenology

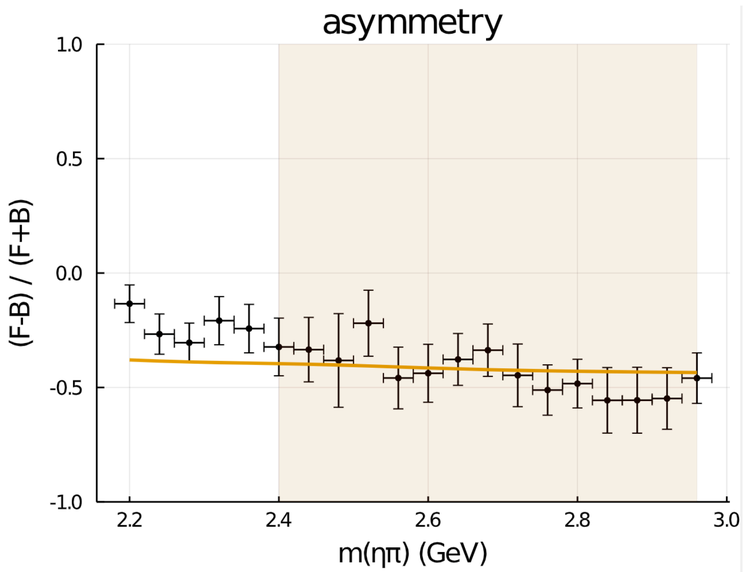


JPAC collaboration

Bibrzycki, Fernández-Ramírez, Mikhasenko, VM et al
work in progress

Fit COMPASS data with double Regge amplitudes





F/B asymmetry responsible for exotic odd waves

Websites

Event generator for XYZ@EIC

https://github.com/dglazier/elSpectro

Coordinator: Derek Glazier

JPAC Interactive webpage

https://ceem.indiana.edu/jpac

Coordinator: VM

Photoproduction:

1. High energy model for tensor meson photoproduction: $\gamma p \to Tp$ page
2. High energy model for $\gamma p \to \eta\pi^0 p$ and di-meson moments: $\gamma p \to \eta\pi^0 p$ page
3. High energy model for $\gamma N \to \pi N$ constrained by FESR: $\gamma N \to \pi N$ page
4. High energy model for ρ^0, ω, ϕ spin density matrix elements: $\gamma p \to Vp$ page
5. High energy model for η' beam asymmetry photoproduction: $\gamma p \to \eta^{(\prime)} p$ page
6. High energy model for η photoproduction: $\gamma p \to \eta p$ page
7. High energy model for π^0 photoproduction: $\gamma p \to \pi^0 p$ page
8. Model for J/ψ photoproduction $\gamma p \to J/\psi p$: unpolarized observables ; polarized observables

Hadroproduction:

1. Pion-nucleon Scattering:
   - Amplitudes $\pi N \to \pi N$ amplitude page
   - Finite energy sum rules $\pi N \to \pi N$ FESR page
2. Kaon-nucleon scattering: $\bar{K}N \to \bar{K}N$ page

Three-body Decay: Isobar decomposition and recoupling coefficients.
Light Meson Decay:

1. η meson into three pions: $\eta \to 3\pi$ page
2. vector meson into three pions: $\omega, \phi \to 3\pi$ page

Heavy Baryon Decay:

1. $\Lambda_b^0 \to J/\psi p K^-$ and the $P_c(4312)^+$: $P_c(4312)^+$ page

ALICE Group in Catania

Coordinator: Angela Badalà

Measuring p_T spectra of in different multiplicity bins of $K^*(982)^{\pm} \rightarrow \pi K$ in pp at 13 TeV

Developing Machine Learning technique to identify resonances

Training on $K^*(892)^0 \rightarrow \pi K$ to improve recognition in $pb\ pb$ collisions

Futur plan: applying on $\Omega(2012) \rightarrow \Xi K$ in pp at 13 TeV

BESIII Group in Turin

Coordinator: Marco Destefanis

Matching pQCD with data

Investigation of the interference
between hadronic and electromagnetic processes

proton-antiproton final states

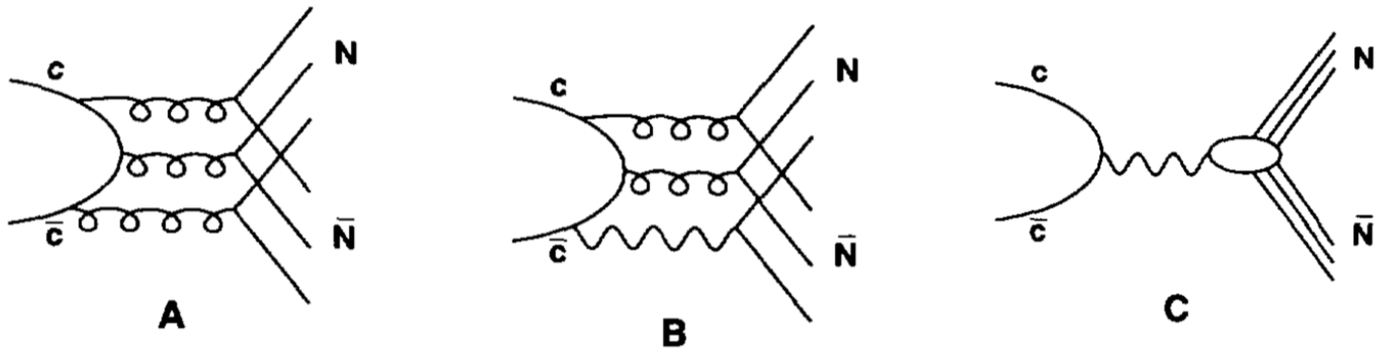
$e^+e^- \to J/\psi \to p\bar{p}$ vs $e^+e^- \to p\bar{p}$

ROOT implementation of fitting routine

M. Ablikim et al. PRD86 032014 (2012)

Theoretical prediction from

Baldini, Bini and Luppi
PLB404 (1997) 362



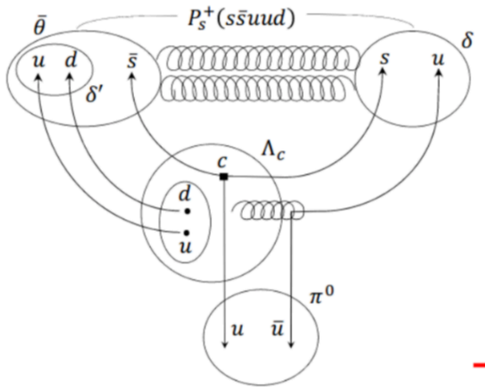
BESIII Group in Ferrara

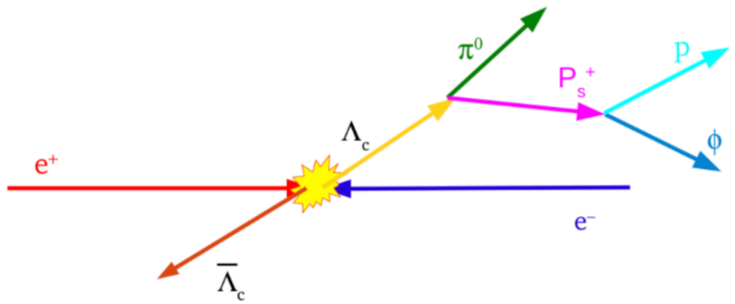
Ferrara group	Position	Activities
Isabella Garzia	Researcher (UNIFE)	Coordinator/Analysis
Gianluigi Cibinetto	Researcher (INFN)	Coordinator/Analysis
Giulio Mezzadri	Postdoc	Analysis
Ilaria Balossino	Postdoc	Analysis
Marco Scodeggio	PhD student	Analysis

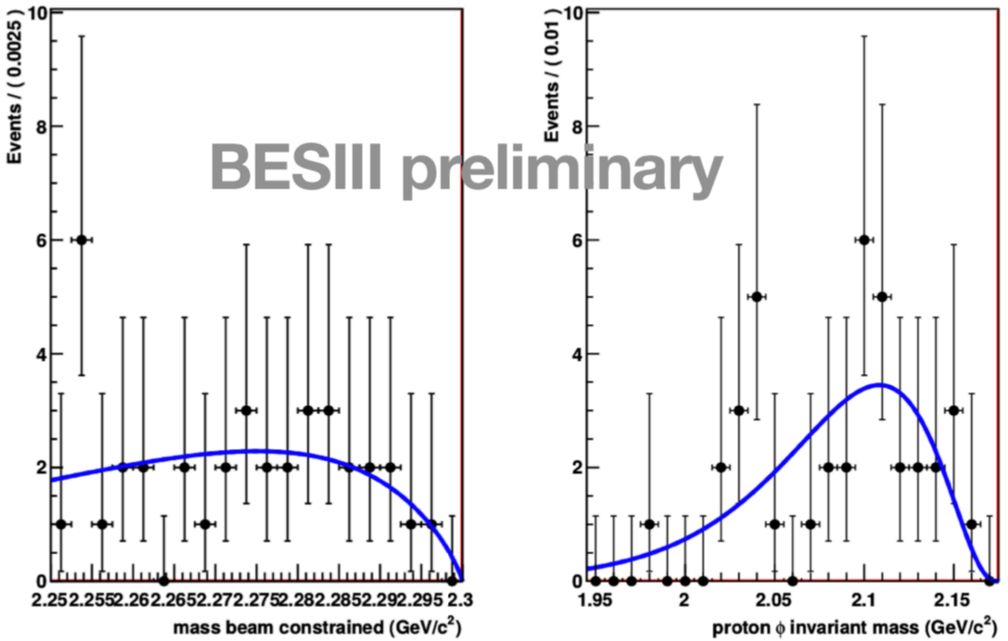
Search for hidden-strangeness pentaquark in Λc decay at BESIII

Stimulated by LHCb and Belle observation, in BESIII we peached for a hidden-strangeness pentaquark in Λc decay

- In 2014, BESIII has collected 567 pb^{-1} close to $\Lambda_c\overline{\Lambda}_c$ production threshold (4.6 GeV)
  - The pentaquark is searched in the pϕ invariant mass
  - The result is limited by statistic
  - No evidence of signal is found
  - **PLANS: BESIII has collected new data between 4.6 to 4.7 GeV in 2020—> this analysis will be updated**







BESIII Group in Ferrara

Inclusive measurement of hc in the psi(2S) decay

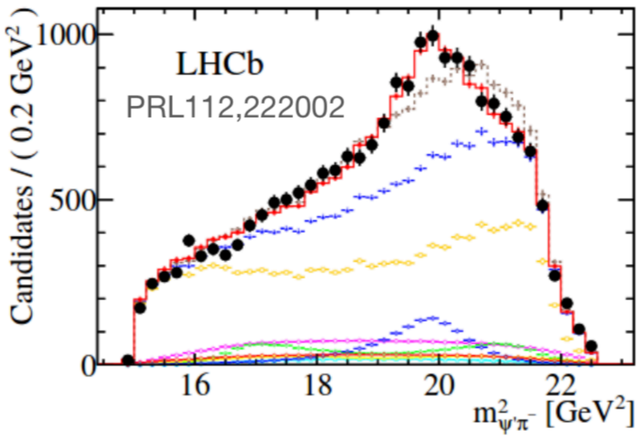
Ongoing analysis

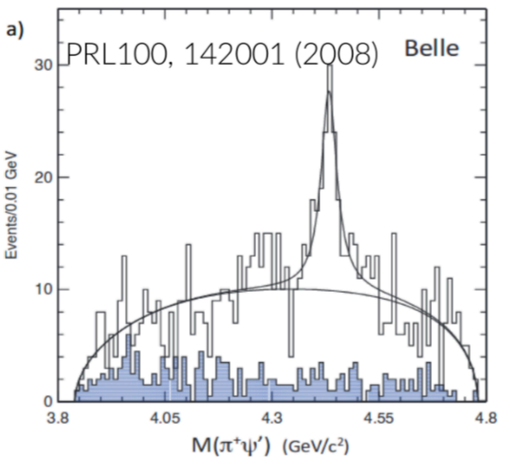
- **From April 2019:**
  - Event and track selection validation
  - Systematic uncertainty studies finalised
- **This year (2020):**
  - BESIII internal document released
  - Internal review started
- **PLANS:**
  - Prepare the draft
  - Submission to journal (2021)

BESIII Group in Ferrara

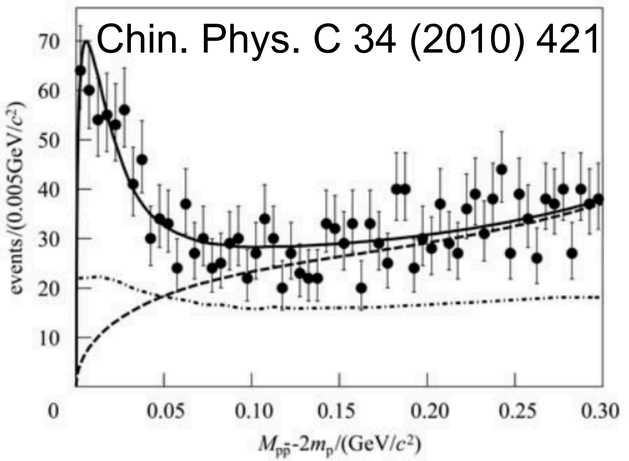
BESIII - New analysis started very recently: e+e- -> Y(4660) -> Zc-/+ (4430) pi+/- -> psi(2S) pi+/- pi+/-

- Zc(4430) observed first by Belle Collaboration and confirmed by LHCb
- In 2020, BESIII took new data up to 4.7 GeV
  - we plan to search for Zc(4430) in BesIII by means of this new data set and to study possible connection with the nearby Y(4660) resonance
  - **PLANS (from Autumn 2020):**
    - start of the analysis: signal MC production ongoing (resonant and non resonant)
    - Study the analysis feasibility
    - Plan to have event selection cut by min winter 2020/2021





BESIII Group in Ferrara



Plans for new analyses (with BESIII data)

- Two new analyses planned by our group for the next year:
  - Search for X(1835) in Jpsi—> ωX(1835), X(1835)→ η'π+π- hadronic decays
    - improve the analysis published on PRD99,071101 (published on April 2019) with the full Jpsi statistics collected by BESIII in the 2018 and 2019 (10 billion of Jpsi data)
  - BR measurement of Jpsi—> ϕ η'π+π-, and search for X(1835) into η'π+π- invariant mass spectra

Summary

New developments since June 2019 in the network STRONG-2020

Theory

Spectra and decays of light and heavy hybrids from EFT and pNRQCD

Tools

Moments of photoproduction of 2 pseudo scalar mesons

Kinematics for 3-body decays

Webpages with codes

Particle ID with Machine L.

Analyses

$K^*(982)$ and $\Omega(2012)$ with ALICE

Test of pQCD in $p\bar{p}$ with BESIII

Pentaquark search in Λ_c decay with BESIII

$Z_c(4430)^+$ and $X(1835)$ search with BESIII

Summary

New developments since June 2019 in the network STRONG-2020

Theory

Spectra and decays of light and heavy hybrids from EFT and pNRQCD

Tools

Moments of photoproduction of 2 pseudo scalar mesons

Kinematics for 3-body decays

Webpages with codes

Particle ID with Machine L.

Analyses

$K^*(982)$ and $\Omega(2012)$ with ALICE

Test of pQCD in $p\bar{p}$ with BESIII

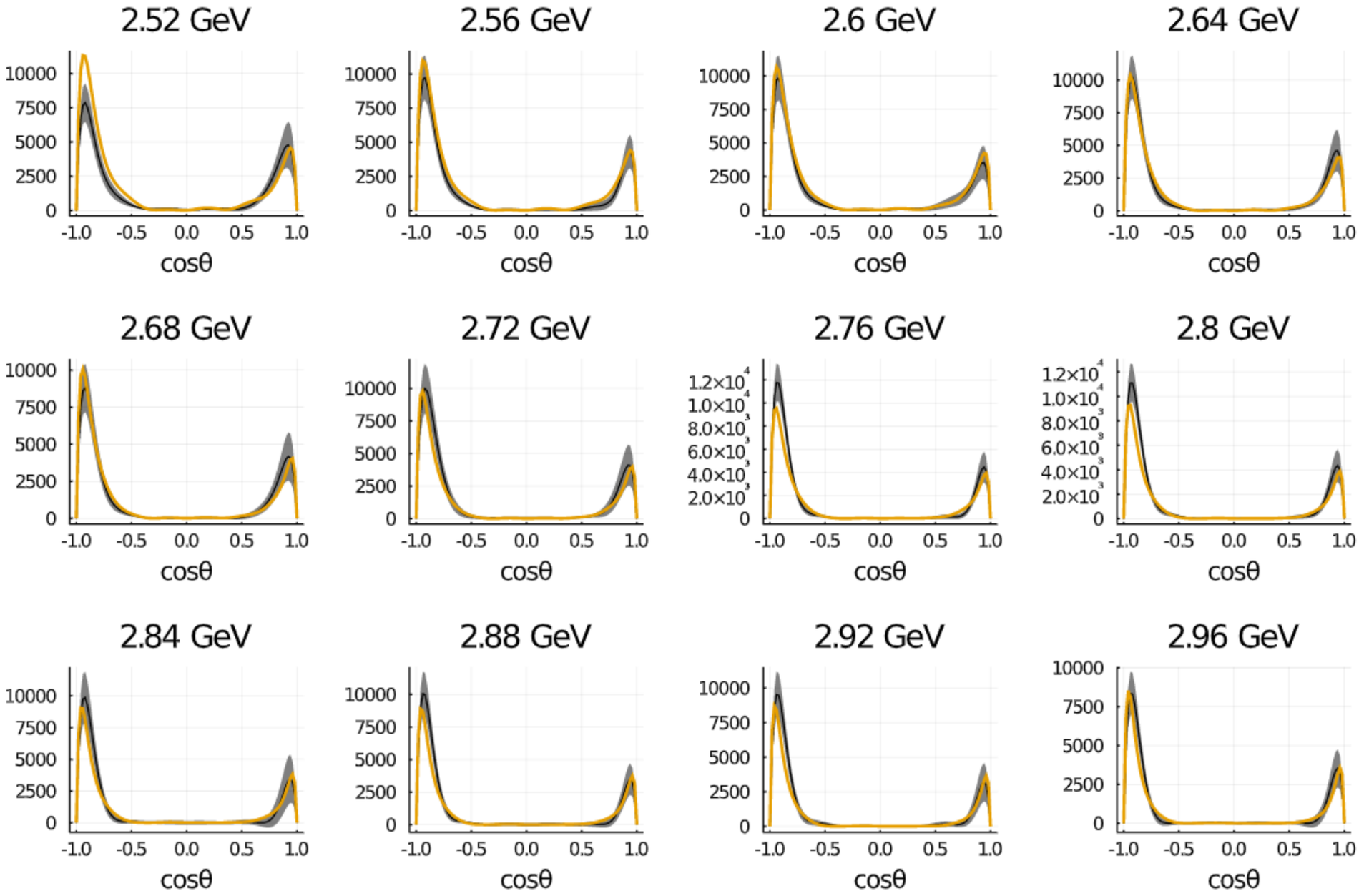
Pentaquark search in Λ_c decay with BESIII

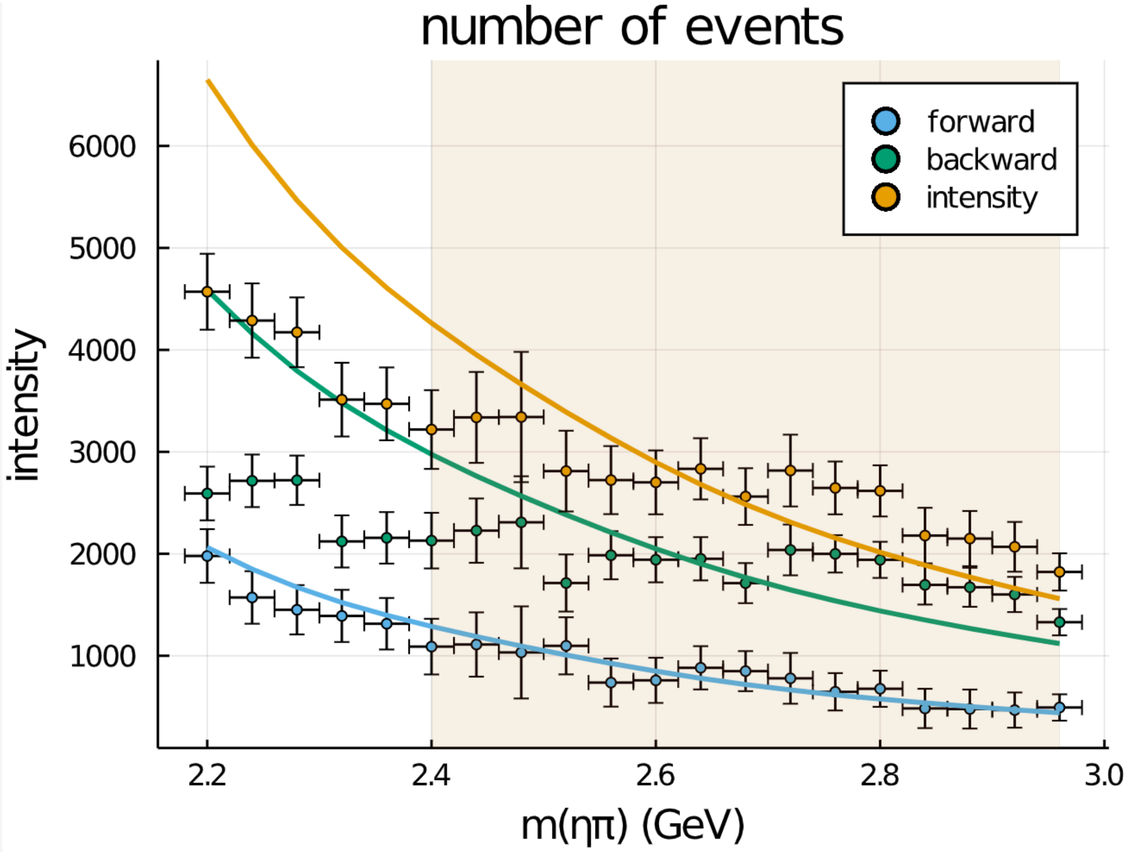
$Z_c(4430)^+$ and $X(1835)$ search with BESIII

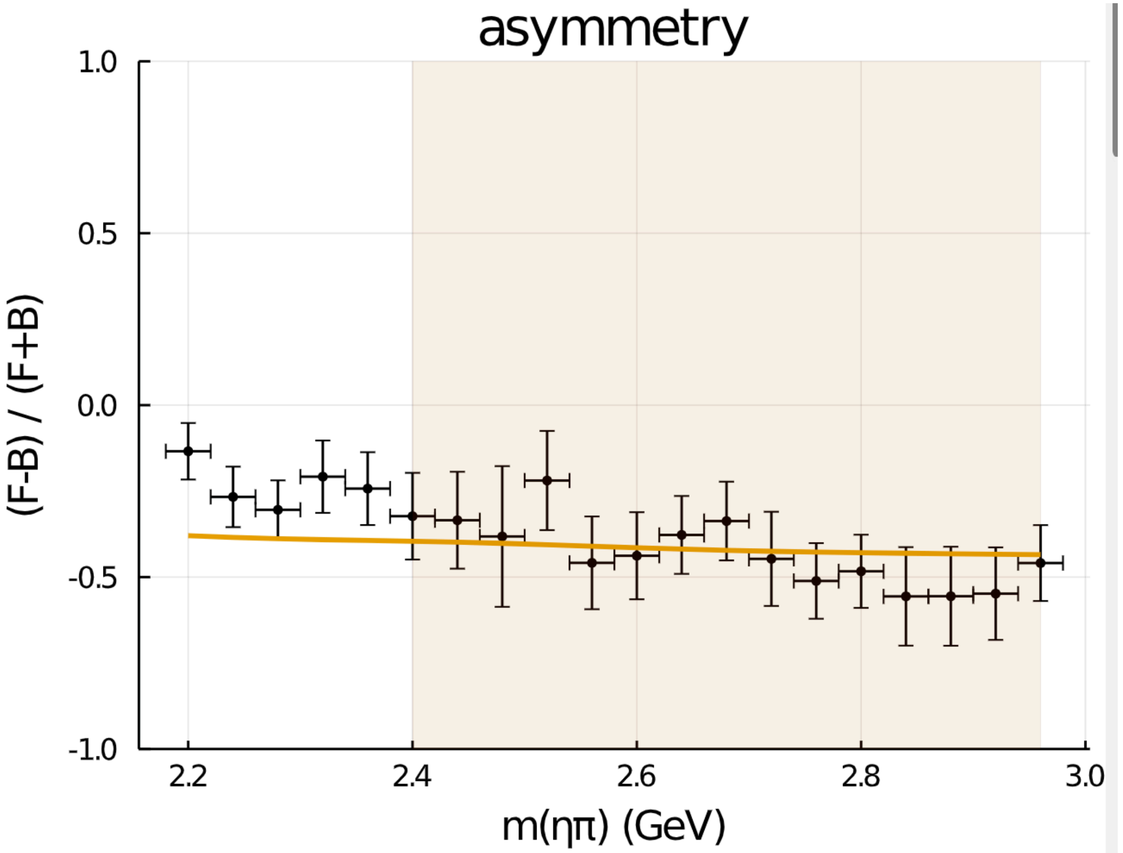
Other developments in Task 3.1 missing? (LHCb from Neubert?)

Don't hesitate to contact me

Backup Slides


2.52 GeV
2.56 GeV
2.6 GeV
2.64 GeV
2.68 GeV
2.72 GeV
2.76 GeV
2.8 GeV
2.84 GeV
2.88 GeV
2.92 GeV
2.96 GeV
cosθ


number of events
forward
backward
intensity
6000
5000
4000
3000
2000
1000
intensity
2.2
2.4
2.6
2.8
3.0
m(ηπ) (GeV)


asymmetry
1.0
0.5
0.0
-0.5
-1.0
(F-B) / (F+B)
2.2
2.4
2.6
2.8
3.0
m(ηπ) (GeV)

Estimation of XYZ Cross Sections @EIC

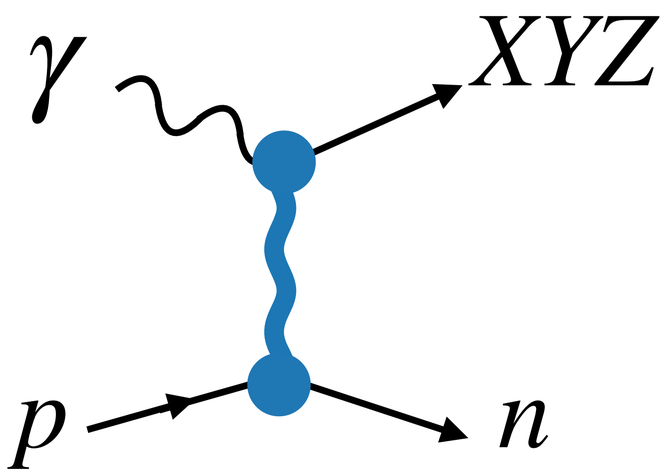
JPAC collaboration

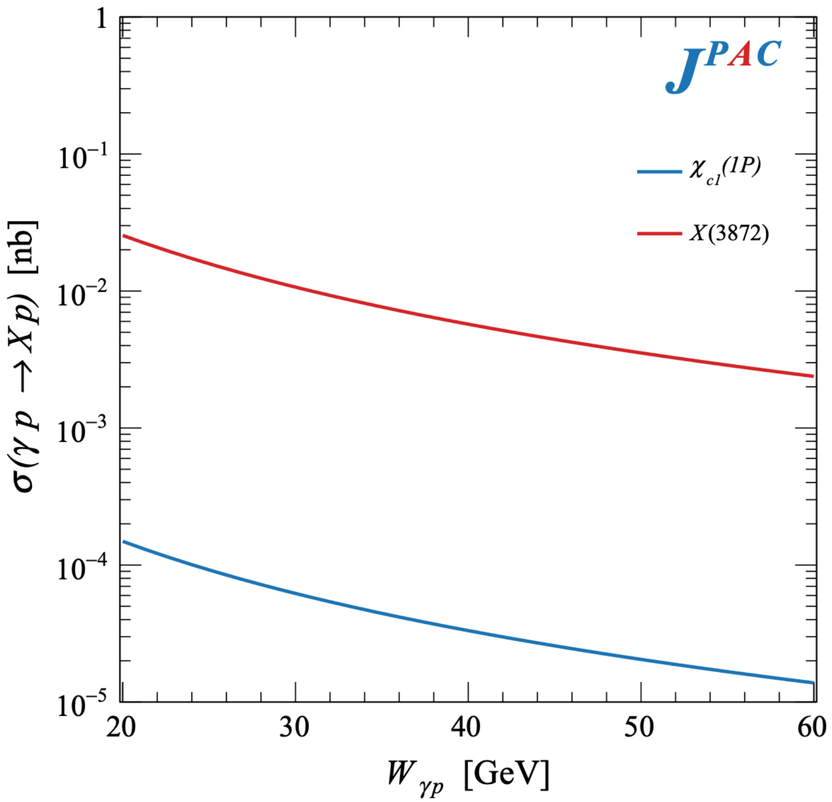
Albaladejo, Hiller-Blin, Pilloni, Winney, Fernández-Ramírez, VM and Szczepaniak
PRD102 (2020) 114010

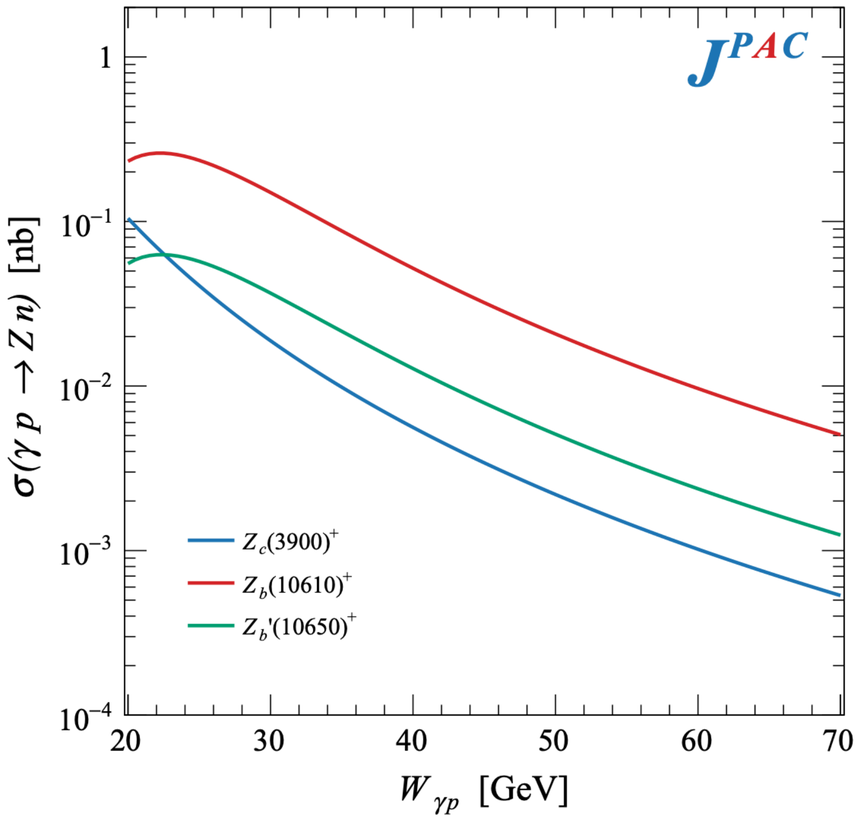
Cross sections prediction for

$X(3872), X(8900), Y(4260)$

$Z_c(3900)^+, Z_b(10610)^+, Z_b(10650)^+$





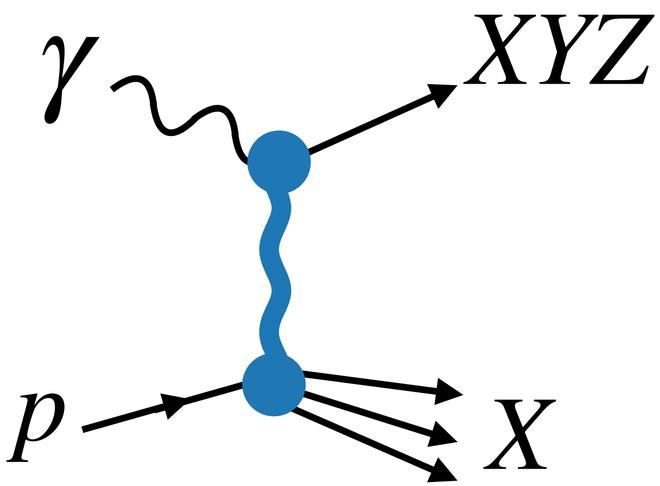
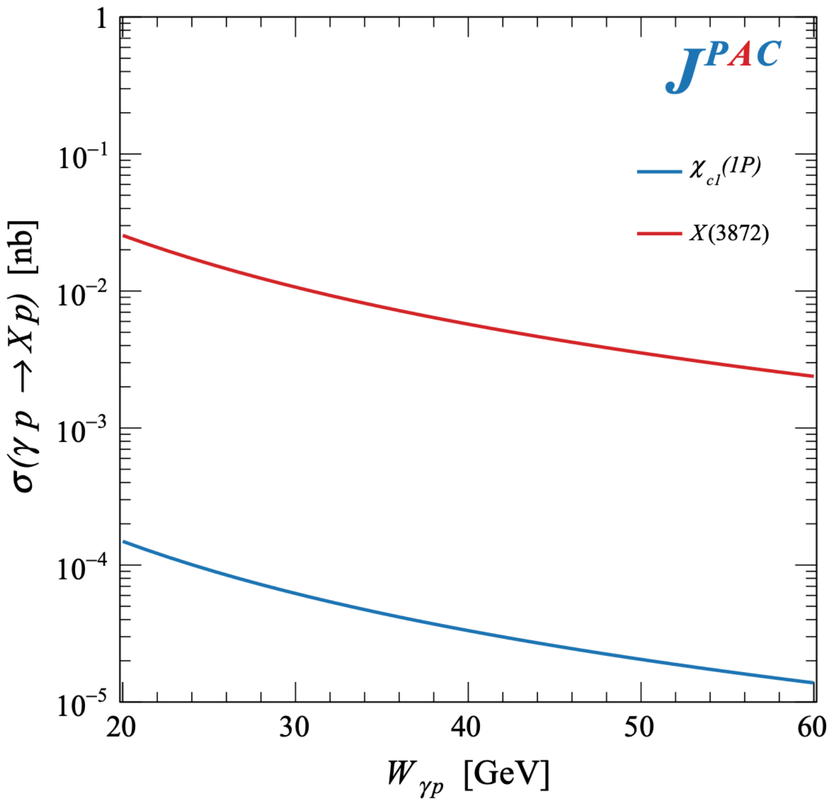
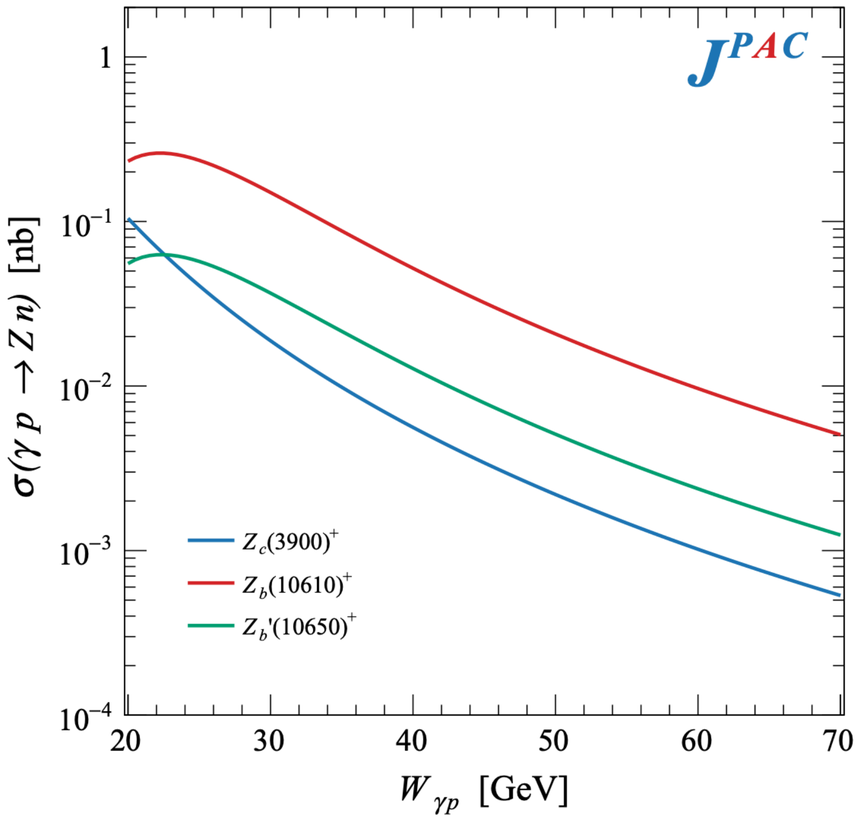


Estimation of XYZ Cross Sections @EIC

JPAC collaboration

Albaladejo, Hiller-Blin, Pilloni, Winney, Fernández-Ramírez, VM and Szczepaniak
PRD102 (2020) 114010

Cross sections prediction for

$X(3872), X(8900), Y(4260)$

$Z_c(3900)^+, Z_b(10610)^+, Z_b(10650)^+$