Recent Results From

The Joint Physics Analysis Center

Amplitudes, experiments, and people
at the heart of hadron spectroscopy

Adam Szczepaniak Jefferson Lab · 2026

OUTLINE

Where we are going

I **What JPAC is**
Origin, structure, the people who built it

II **Support for JLab & training**
Shared frameworks across six collaborations; schools & the career pipeline

III **Recent scientific results**
Eight papers across three themes

IV **AI & machine learning**
Theory, data analysis, and four Genesis proposals

V **Outlook**
The next ten years — and three takeaways

PART I · WHAT JPAC IS

Ten years of meetings — JLab, Munich, Bochum, Genoa, plus weekly virtual ones.

From a JLab12 commitment to a global node

2013	2016	2022	2026
Operations begin	**3-year review**	**10-year review**	**Today**
Need for more theory integration with experimental analyses	*Effective day-to-day management praised*	*Renewal for 10 more years recommended*	*Hybrid harvest era Lattice + EIC ahead*

16	9	30+	13
Full members	**Affiliated members**	**Researchers in 10y**	**PhDs awarded**

FDSA workshop series

Future Directions in Spectroscopy Analysis — four editions to date

Summer schools

Annual school at UNAM; co-organized NNPSS 2021 during COVID

Graduate courses

Indiana University, Messina, UNAM, JLab user groups

Conferences & workshops

Organizing roles across HADRON, CIPANP, QNP & INT / ECT* programs

Reviewers in 2022: "deep respect, trust, and commitment" of early-career scientists to JPAC leadership.

No formal hierarchy, consensus-driven — sustained by annual meetings (JLab, Munich, Bochum, Genoa) and weekly virtual ones.

MENTORSHIP IN NUMBERS

Where JPAC people are, today

PART II · SUPPORT FOR JLAB

GlueX *JLab Hall D*
Majority of analyses

CLAS / CLAS12 *JLab Hall B*
Single-meson photoproduction

LHCb *CERN*
Dalitz formalism in Pc, Tcc papers

BESIII *IHEP, Beijing*
Data-driven amplitude analyses

COMPASS *CERN*
$\eta^{(\prime)}\pi$ reanalysis, π-beam studies

BaBar *SLAC*
Three-body final states

100%

of postdocs now in permanent positions

SELECTED PLACEMENTS

C. Fernández-Ramírez
Prof., UNED · Madrid

A. Jackura
Asst. Prof., W&M · Virginia

I. Danilkin
Permanent, JGU Mainz · Germany

S. Dawid
Asst. Prof., Indiana U. · Bloomington

V. Mathieu
Assoc. Prof., UB · Barcelona

Ł. Bibrzycki
Asst. Prof., AGH · Kraków

A. Pilloni
Assoc. Prof., Messina · Italy

M. Mikhasenko
Assoc. Prof., Bochum · Germany

A. Rodas
Asst. Prof., ODU · Virginia

J. Nys
Research Sci., ETH Zürich · Switzerland

S. González-Solís
Asst. Prof., UB · Barcelona

P. Guo
Assoc. Prof., Dakota State · USA

M. Albaladejo
Ramón y Cajal, IFIC · Valencia

L.-Y. Dai
Hunan U., Changsha · China

The culture change — ship working, fittable code, not a paper of formulas — has compounded across the global spectroscopy program.

Ten years, compounding: cumulative output

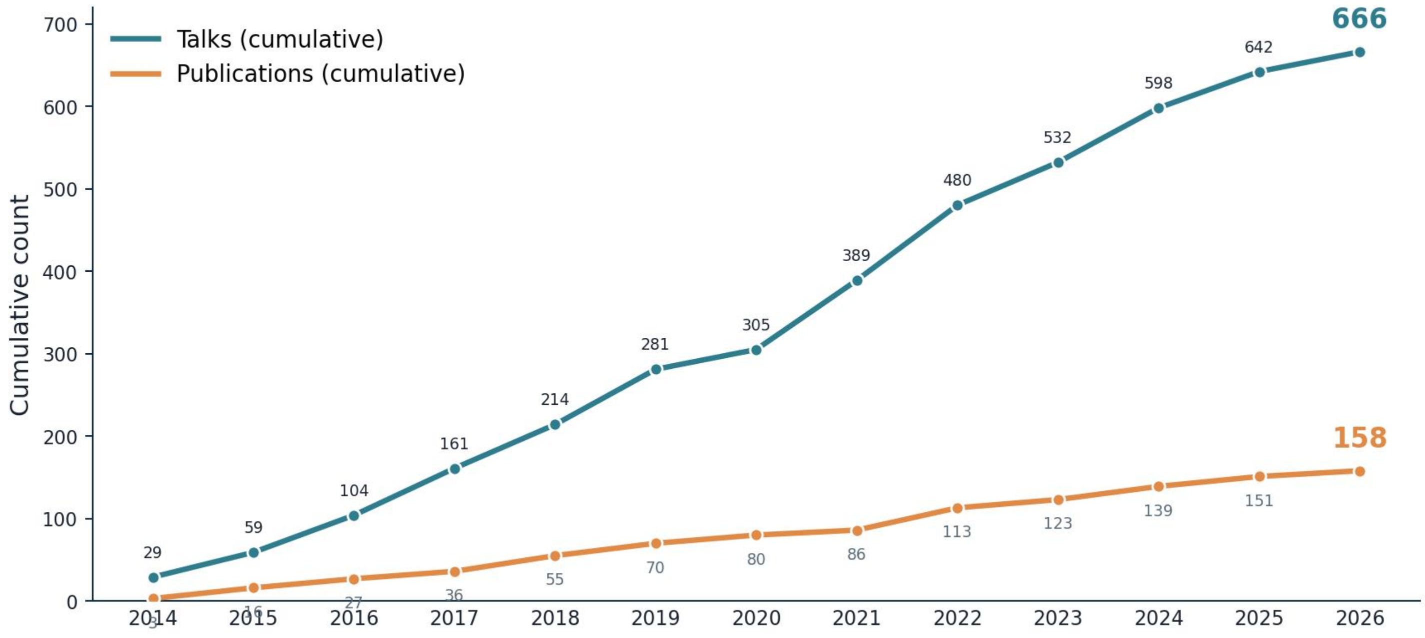
THE FLAGSHIP TOOL

jpacPhoto

Unified amplitude-analysis framework for photoproduction.

Built on ROOT · interfaces AmpTools · open on GitHub

github.com/JeffersonLab/jpacPhoto



666

talks, 2014–26

158

papers, 2014–26

Running totals of all entries listed at jpac-physics.org. 2026 is a partial year; the curves are still climbing.

PART III

Eight recent results · three themes

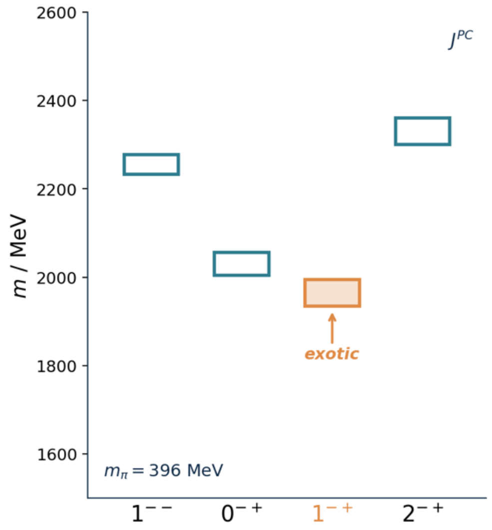
Light mesons · hidden charm · the lattice-QCD frontier

1 **Light-meson photoproduction**
5 papers

2 **Hidden charm & XYZ**
2 papers

3 **Coupling to lattice QCD**
1 paper

Hybrids, confinement, and the hunt for poles



Lightest hybrid supermultiplet from lattice QCD (after Dudek et al.)

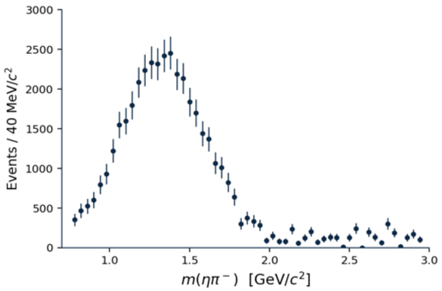
Lattice QCD predicts a hybrid supermultiplet — including the exotic 1^{-+}. The question is whether it shows up as a pole in real data.

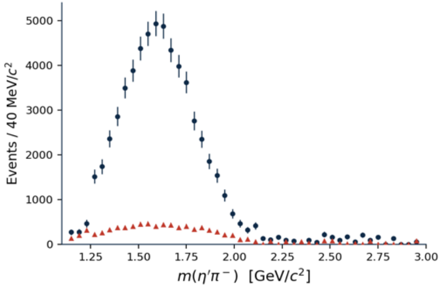
- For infinitely heavy quarks, the gluonic field collapses to a confining string; its excitations define a hybrid's quantum numbers.
- What is a constituent gluon — a string vibration or an excited quasiparticle? Each picture predicts a different pattern of degenerate multiplets.
- The exotic 1^{-+} cannot be an ordinary $\bar{q}q$ meson — its discovery is the cleanest signature of gluonic excitation.
- Lattice gives masses, not line shapes. Real data requires amplitude analysis to find resonance poles in the complex plane.

What about real data? — the next five papers turn the lattice picture into pole searches.

Two spin-exotic candidates

Both carry exotic quantum numbers $J^{PC} = 1^{-+}$ — forbidden to ordinary $q\bar{q}$ mesons. Two states, or one?





$\pi_1(1400)$ seen in **ηπ**

Mass 1354 ± 25 MeV · Width 330 ± 35 MeV

Decays: $\eta\pi^0$ (seen), $\eta\pi^-$ (seen), $\eta'\pi$

$\pi_1(1600)$ seen in **$\eta'\pi$, $\pi\pi\pi$, $\rho\pi$, $b_1\pi$, …**

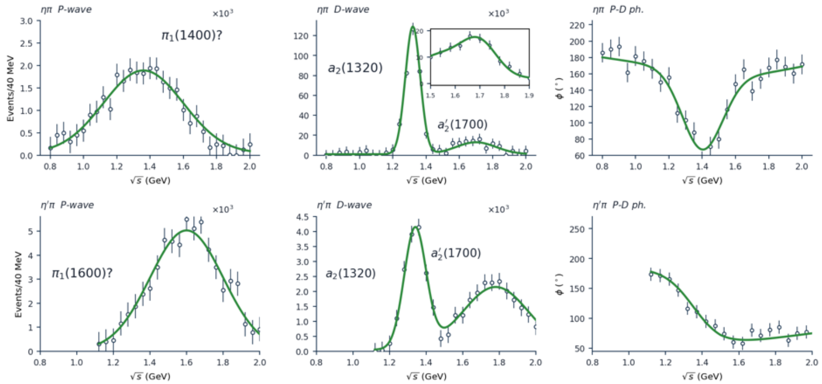
Mass $1662\ ^{+8}_{-9}$ MeV · Width 241 ± 40 MeV

Decays: $\pi\pi\pi$, $\rho^0\pi^-$, $b_1(1235)\pi$, $\eta'(958)\pi^-$, $f_1(1285)\pi$ (seen); $f_2(1270)\pi^-$ (not seen)

Numerical values: PDG. Invariant-mass spectra shown schematically.

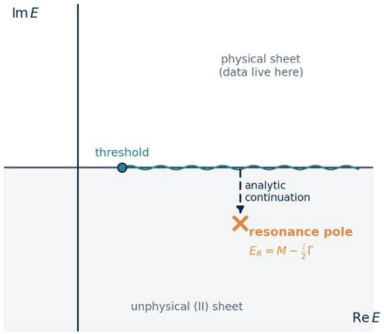
From coupled-channel fits to poles

Coupled-channel fit to ηπ and η′π

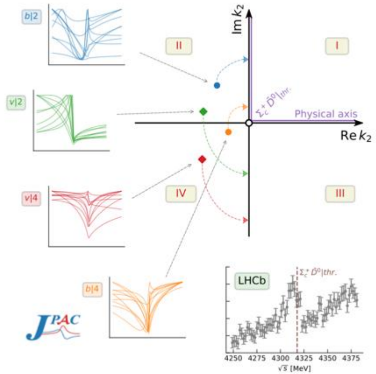


P-wave (π_1 candidates) and D-wave (a_2 family) intensities plus the P–D relative phase, fit simultaneously across both channels. Shown schematically.

What a resonance really is: searching for poles



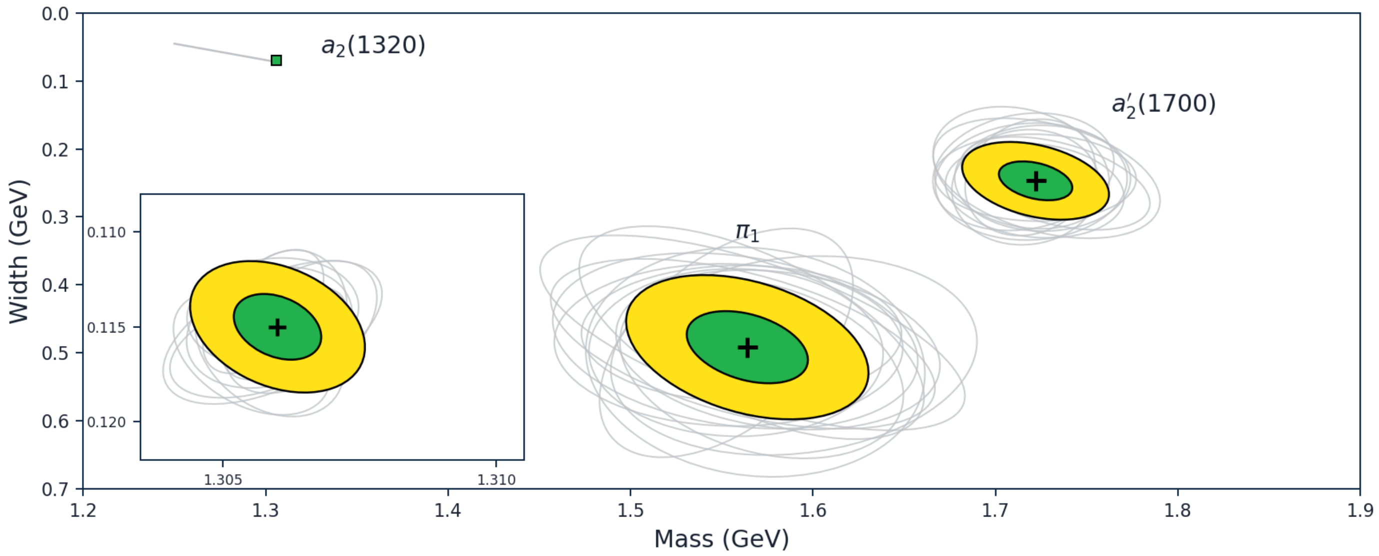
Bumps are not resonances. A resonance is a pole of the scattering amplitude on the unphysical sheet, and finding it is the whole game.



- The pole position fixes mass and width; residues fix the couplings — model- and process-independent.
- Build amplitudes with the right analyticity, unitarity, and crossing; fit on the real axis, then continue onto the unphysical sheet to locate the pole.
- Sheet location distinguishes a genuine exotic from a cusp or threshold artifact.

This is what every JPAC light-meson analysis ultimately delivers: pole positions, not bumps.

Final results: poles in the complex plane



Pole	Mass (MeV)	Width (MeV)
$a_2(1320)$	1306.0 ± 0.8 ± 1.3	114.4 ± 1.6 ± 0.0
$a_2'(1700)$	1722 ± 15 ± 67	247 ± 17 ± 63
π_1	**1564 ± 24 ± 86**	**492 ± 54 ± 102**

Most rigorous π_1 pole extraction to date

Five papers feeding the hybrid search

2510.14549	2406.08016	2407.19577	2604.22719	HADRON 2025
$\eta^{(\prime)}\pi$ high-energy photoproduction model	$\pi^+\pi^-$ photoproduction beyond Pomeron	Gauge-invariant Reggeized pion	$\pi^-\Delta^{++}$ polarized photoproduction	$\eta\pi$ finite-energy sum rules (FESR)

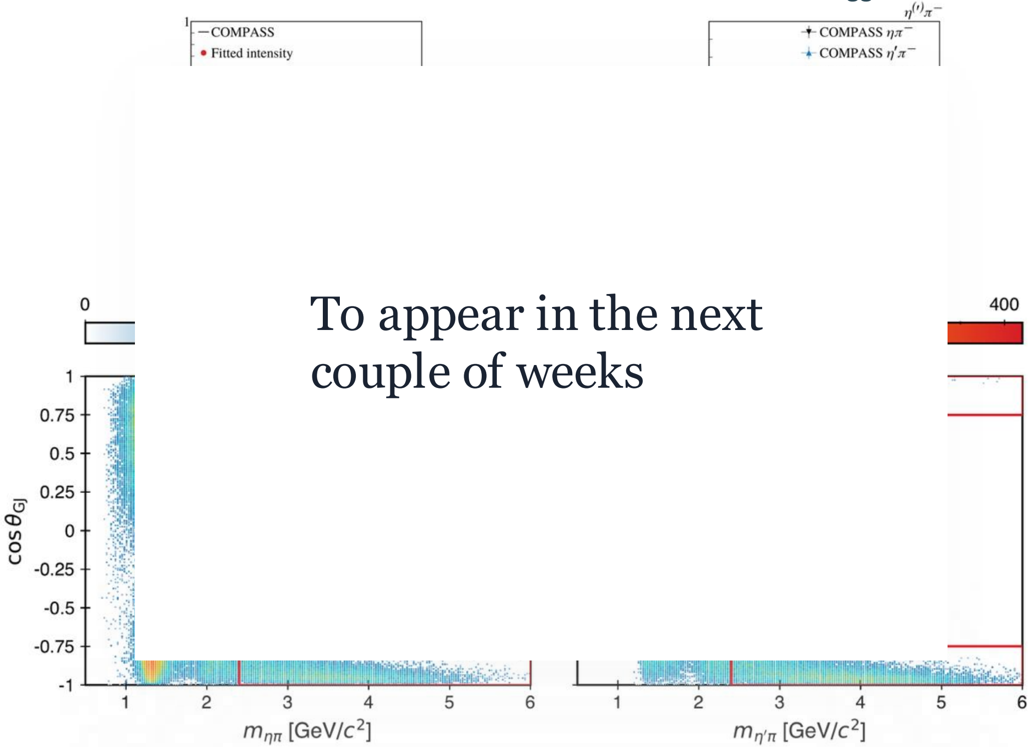
All five papers feed directly into the hybrid-meson amplitude framework used by GlueX.

JPAC/COMPASS analysis

$$A(m_{\eta\pi}) = \frac{F(m_{\eta\pi}) - B(m_{\eta\pi})}{F(m_{\eta\pi}) + B(m_{\eta\pi})}$$

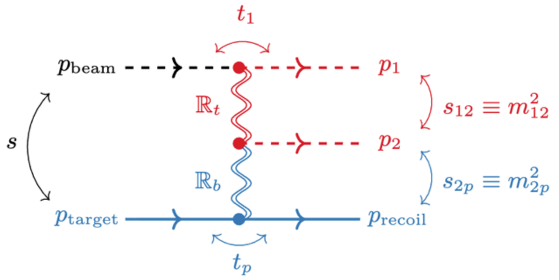
Without π_1 Reggeon

With π_1 Reggeon



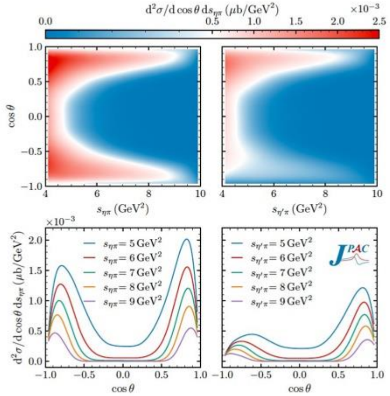
To appear in the next couple of weeks

- Backward/fast π
  - top exchange connects: $\pi^- \rightarrow \pi^-$
  - leading exchanges: $\mathbb{R}_t = \mathbb{P}, f_2$
  - Odd spin exchanges are forbidden by Bose symmetry
- Forward / fast $\eta^{(\prime)}$
  - top exchange connects: $\pi^- \rightarrow \eta^{(\prime)}$
  - allowed natural-parity isovector exchanges: $\mathbb{R}_t = a_2, a_2', \pi_1$ where
    - a_2: leading ordinary positive-signature
    - a_2': subleading ordinary positive signature exchange
    - **π_1: exotic negative-signature**



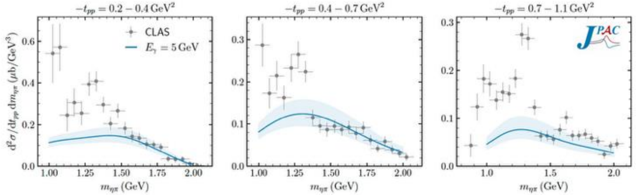
Why it matters: Like Veneziano duality, exotic Reggeon appear to be dual to exotic resonances, and not, for example, to meson-pomeron cuts. Can be produced via charge exchange, e.g., in $\pi_1^-(1600)\Delta^{++}$

$\eta^{(\prime)}\pi$ photoproduction & the nature of exotic waves



arXiv:2510.14549 *Jan 2026 · Montaña, Mathieu, Shastry et al. (JPAC)*

> *A parameter-free Reggeized double-vector model that already reproduces CLAS — and predicts what GlueX will see.*



- Double-vector exchange model with Reggeized ρ and ω trajectories.
- No free parameters — fully constrained by trajectories and known couplings.
- Reproduces the magnitude and t-dependence of CLAS data at Eγ = 5 GeV.
- Predicts stronger forward-backward asymmetry in η′π than in ηπ, matching COMPASS pion-beam data.

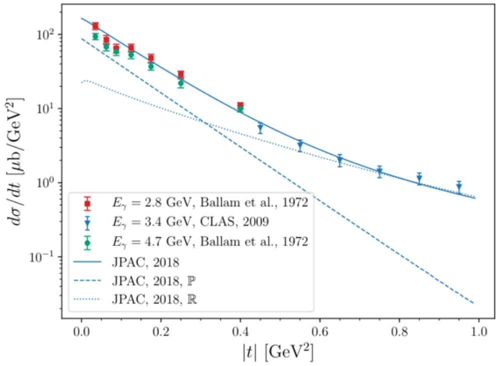
Why it matters: Gives the GlueX $\pi_1(1600)$ search a controlled non-resonant baseline.

$\pi^+\pi^-$ photoproduction beyond Pomeron exchange

arXiv:2406.08016 *June 2024 · Bibrzycki, Hammoud, Mathieu et al. (JPAC)*

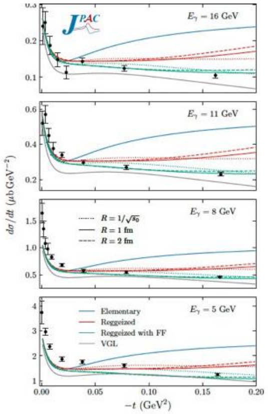
The textbook Pomeron-dominance assumption breaks down at moderate momentum transfer — and now you know where.

- Detailed analysis of CLAS $\pi^+\pi^-$ photoproduction data in the ρ-mass region.
- Shows Pomeron exchange alone cannot describe data for $|t| \gtrsim 0.5$ GeV².
- Identifies and quantifies the additional exchanges required.
- Tightens the description of a channel widely used as a GlueX calibration.



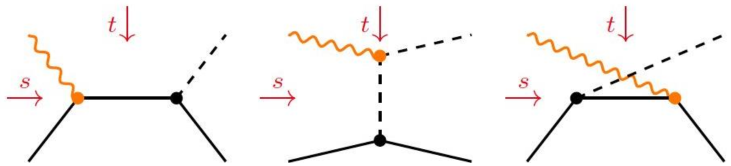
Why it matters: Any analysis using $\pi^+\pi^-$ as a reference channel now has a known, quantified systematic.

Gauge invariance and Reggeization of pion exchange



arXiv:2407.19577 2025 · *Montaña, Winney, Bibrzycki et al. (JPAC)*

> *Foundational work: a Reggeized pion exchange that is gauge-invariant by construction.*



- Reggeized pion is the dominant amplitude in charged-pion photoproduction at high energies.
- Must respect current conservation when coupled to a real photon — a long-standing subtlety.
- Proves the gauge-invariant amplitude for spin-J ≥ 2 even-spin t-channel exchange is analytic at J = 0.
- Yields a Reggeized pion amplitude that is gauge-invariant and well-behaved across kinematics.

$$A^J_{\lambda_\gamma\lambda_i\lambda_f}(s,t) = \frac{2\sqrt{2}\,e_\pi\, g}{J-\alpha_\pi(t)}\, 2\lambda_i\, \delta_{\lambda_i\lambda_f} \left[J! \sqrt{\frac{2^J}{(2J)!}} \right]^2 \sqrt{\frac{J+1}{2J}}\, (-2\, p_t k_t)^J\, t\, d^J_{\lambda_\gamma,\lambda_i-\lambda_f}(\theta_t)$$

$$= a^J_{\lambda_\gamma\lambda_i\lambda_f}(t)\, d^J_{\lambda_\gamma,\lambda_i-\lambda_f}(\theta_t) \qquad \text{(C7)}$$

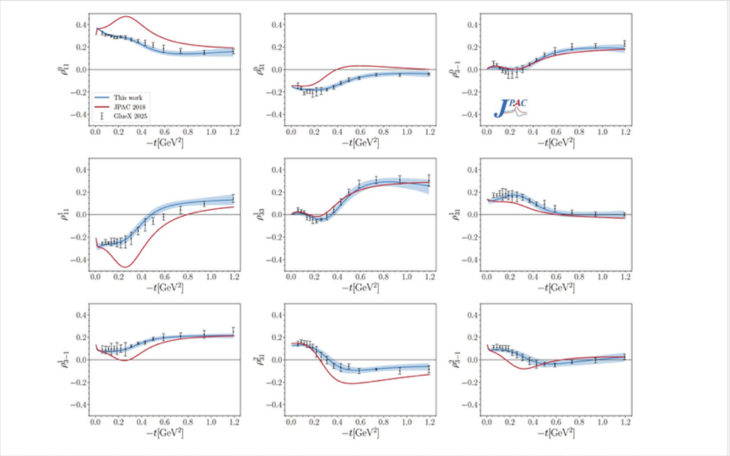
Why it matters: Infrastructure that every downstream charged-pion photoproduction analysis rests on.

High-energy polarized photoproduction of $\pi^-\Delta^{++}$

arXiv:2604.22719 *April 2026 · Shastry, Bibrzycki, Mathieu et al. (JPAC)*

Combining polarized SDMEs with cross-sections pins down both magnitudes and phases — and validates the framework.

- Regge model with π, ρ, b_1, a_2 trajectory exchanges.
- Simultaneous fit to GlueX SDMEs (E_γ = 8.2–8.8 GeV) and SLAC differential cross sections.
- Pion exchange dominates at small t; natural-parity exchanges grow at larger t.
- Extracted πNΔ coupling consistent with the Δ(1232) decay width — a clean closure check.



Spin density matrix elements vs |t|: model curves overlaid on GlueX data, showing the simultaneous fit across multiple SDMEs

Why it matters: Demonstrates how SDME-driven analyses constrain phases that cross-sections leave free.

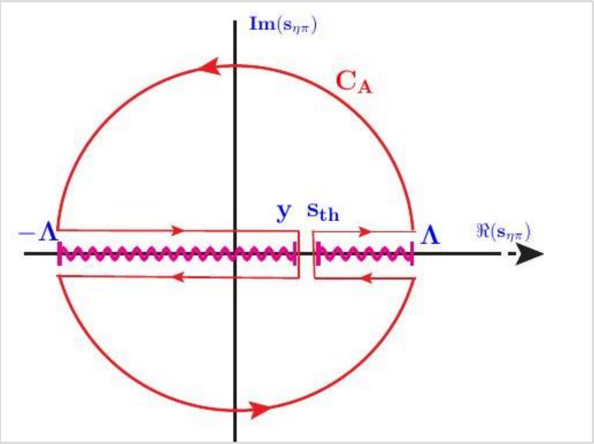
Finite-energy sum rules for $\pi^- p \to \pi^- \eta p$

PoS HADRON2025

March 2025 · Hammoud, Mathieu, Szczepaniak (JPAC)

> *Finite-energy sum rules tie the COMPASS ηπ partial waves to double-Regge exchange — an analyticity bridge for the hybrid search.*

- FESR relate the low-energy ηπ partial waves to high-energy Regge behavior through Cauchy's theorem.
- Double-Regge amplitude saturated by f_2 and Pomeron exchanges; a single-Regge form describes the COMPASS waves.
- Crossed-channel pion exchange supplies a left-hand cut alongside the unitarity right-hand cut.
- Lowest-moment ($j = 0$) sum rule constructed; numerical tests of the $f_2 f_2$ model are underway.



Integration contour in the complex sηπ-plane: left- and right-hand cuts bounded by the cutoff Λ.

Why it matters: An analyticity cross-check of the ηπ amplitudes behind the π_1 hybrid extraction.

Near-threshold J/ψ & XYZ — today and at the EIC

2305.01449

Dynamics in near-threshold J/ψ photoproduction

Model-independent partial-wave baseline using GlueX + J/ψ-007 data

2404.05326

XYZ at electron-hadron facilities III

Semi-inclusive predictions for χ_{c1} and X(3872) with vector exchanges

From present-day Hall D to a 22 GeV upgrade and the EIC — the same group, the same framework.

WHY PHOTOPRODUCTION OF XYZ?

01

A clean discovery frontier

No XYZ state seen uncontroversially in photoproduction — every observation would be new.

02

Rescattering controlled

Resonance-mimicking rescattering is tamed: vary the beam energy

03

Theoretically clean

The production framework is relatively clean from theory — well suited to amplitude analysis.

04

Radiative-decay handle

Radiative decays give a complementary way to discern the nature of the states.

Dynamics in near-threshold J/ψ photoproduction

arXiv:2305.01449 *May 2023 / v2 Sep 2023 · Winney, Fernández-Ramírez, Pilloni et al. (JPAC)*

Get the partial-wave baseline right before claiming pentaquarks, the trace anomaly, or anything else.

- Near-threshold J/ψ photoproduction underlies claims about proton mechanical properties, charmonium-nucleus binding, and hidden-charm pentaquarks.
- These claims rely on VMD or photon-cc̄ factorization — both violated if open-charm intermediate (DD̄) states matter.
- Joint analysis of GlueX and J/ψ-007 data is described by a small number of partial waves with low-energy unitarity.
- Provides a model-independent baseline that any physics interpretation must reproduce.
- Photoproduction is a theoretically clean probe with rescattering controllable via the beam energy.

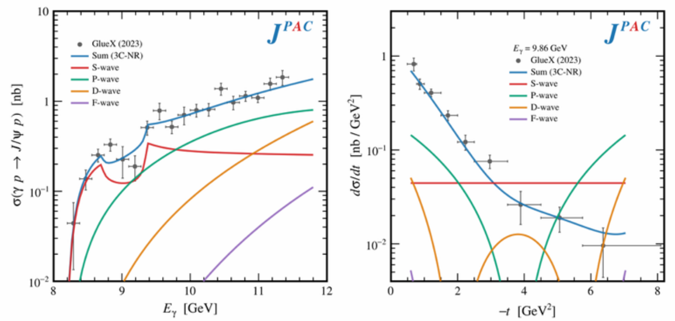


Fig. 5 of arXiv:2305.01449 — Winney et al. (JPAC), Phys. Rev. D 108, 054018 (2023)

Why it matters: Restores discipline: partial-wave baseline first; physics interpretation second.

XYZ spectroscopy at electron-hadron facilities III

arXiv:2404.05326 *April 2024 / v2 June 2024 · Winney, Pilloni, Perry et al. (JPAC)*

> *If the EIC will see X(3872), it will see it semi-inclusively first. Here is the prediction.*

- Inclusive and semi-inclusive cross sections substantially exceed exclusive ones.
- Builds predictions for semi-inclusive χc1(1P) and X(3872) photoproduction with vector exchanges.
- Targets the EIC and a possible 22 GeV JLab upgrade — both in the JPAC ten-year horizon.
- JPAC was the principal driver getting spectroscopy into the EIC Yellow Report.
- No XYZ seen uncontroversially here yet; radiative decays add a handle on their nature.

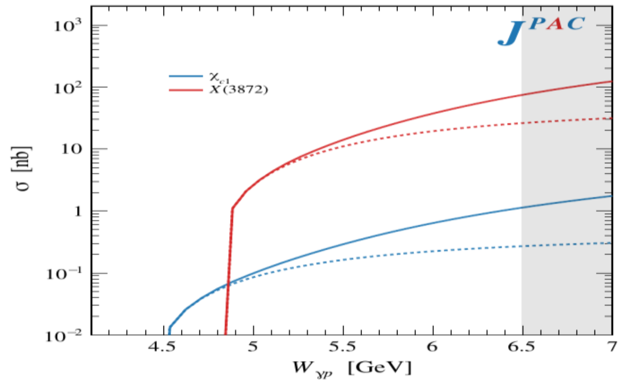


Fig. 8 of arXiv:2404.05326 — Winney et al. (JPAC), 2024

Why it matters: Detector-design-grade numbers for spectroscopy at the next-generation electron-hadron facilities.

Four coordinated Phase I proposals

1

AmplAI — Foundational models for amplitude analysis

Focus Area 14-A (HEP/NP). Lead PI at IU; co-PIs at UVA, W&M, JLab, ODU, Pitt.

2

ALPHA — AI for lattice QCD & petabyte analysis

Focus Area 14-C (NP/HEP). Lead PI A. Jackura (W&M); Adam as Co-Investigator.

3

ALHADIN — Scientific intent into executable HPC code

Focus Area 18-B (ASCR). Lead PI Y. Li (ODU); Adam as collaborator on physics validation.

4

AmpTunes — Neuro-symbolic agents for amplitudes

Focus Area 18-C (ASCR). Lead PI A. Rodas (ODU); Adam as Co-Investigator (IU subaward).

Submitted Spring 2026 under RFA DE-FOA-0003612, assembled across JLab and university partners.

The four near-term goals

1

Complete the GlueX & CLAS amplitude toolkit

Carry the hybrid-meson program to publication-grade results.

2

Broad XYZ program for current + future facilities

Connect present accelerators to the EIC and a 22 GeV JLab upgrade.

3

AI/ML for amplitude extraction (A(I)DAPT)

Universal interpolators, model selectors, parameter-space spanners.

4

Invest in the next generation

Distributed, project-based learning; the JPAC handbook.

Each of the four goals is already visible in the work you just saw.

Thank you

PART IV · AI & MACHINE LEARNING

AI enters the amplitude program

Theory & QCD · data analysis · four Genesis Mission proposals

1. **Theory & QCD**
   neural wavefunctionals, vortices
2. **Data analysis**
   generative unfolding, classifiers
3. **Genesis Mission**
   four Phase I proposals

Neural networks across theory and data

Where amplitudes and lattice data run out, learned representations encode, classify, and unfold.

AI FOR THEORY & QCD

FIELD-BASIS QFT

Variational neural wavefunctional solves Klein–Gordon ground state

POLE CLASSIFICATION

Network sorts Pc(4312) as a virtual state on the 4th sheet

CONFINEMENT

2dVold CNN finds center vortices, no gauge fixing

AI FOR DATA ANALYSIS

GAN UNFOLDING

CLAS 2π closure test unfolds detector effects in 5D

FLOW MATCHING

ScatterPrism CFM surrogate for generation + unfolding

THE DIAGNOSTIC

Physics-informed metrics, not loss, track true fidelity

1

JPAC enables JLab's analysis throughput

Without the shared amplitude framework, every paper would re-invent its own. The 2022 review was emphatic on this.

2

JPAC is now a global node, not a JLab service

The formalisms developed for JLab kinematics sit inside LHCb, COMPASS, BESIII analyses. DOE investment has compounded internationally.

3

The people pipeline is real and paying out

The three founding postdocs all in permanent positions. Thirteen PhDs awarded, seven more in flight. A growing alumni network training their own students.

THE 2022 REVIEW COMMITTEE

Recommended a ten-year renewal,
citing the GlueX hybrid program as a flagship
that will take well over five years to complete.

Eighteen months of subsequent results have only strengthened that case.

Where the next decade lives

Lattice spectroscopy is hitting the left-hand-cut problem.
JPAC has built the formalism to handle it.

THE PROBLEM

Lüscher quantization breaks down near left-hand cuts

THE FIX

Finite-volume N/D representation with analytic left-hand cut

THE DEMO

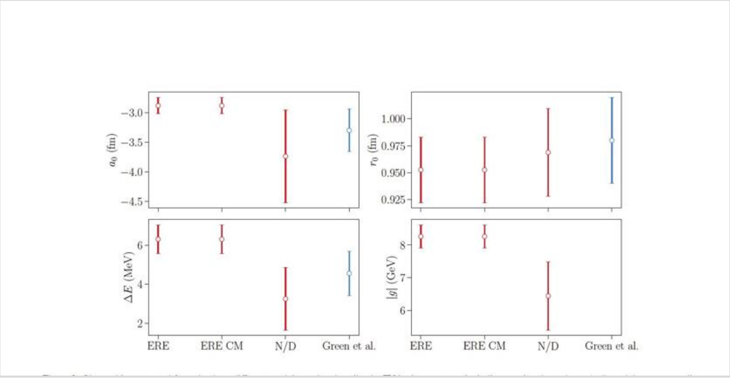
H-dibaryon at the SU(3)F point, $m_\pi \approx 417$ MeV

Finite-volume analysis of the H-dibaryon with left-hand cuts

arXiv:2605.22957 *May 2026 · Rodas, Qiu, Fernández-Ramírez et al. (JPAC)*

On real lattice data, including the left-hand cut shifts the binding energy by a small but statistically real amount.

- Implements the finite-volume N/D representation for two-baryon systems.
- Incorporates the left-hand cut from one-pion exchange analytically.
- Applies to H-dibaryon lattice data at the SU(3)F-symmetric point ($m_\pi \approx$ 417 MeV).
- Direct comparison to the Lüscher analysis of the same data shows a mild but significant shift in the binding energy.



Four observables — a_0, r_0, ΔE, $|g|$ — from three FV models (red) vs the near-threshold fit of Ref. [63] (blue).

Why it matters: Methodological template for every interesting lattice channel: NN, Tcc, X(3872), and beyond.