

The Synergy between JLab and J-PARC: A Unified Framework Across Multi-Experiment Vector Meson Physics Programs

Igor Strakovsky

The George Washington University



- Once upon a time, there was a Vector Meson....
- JLab for Threshold J/ψ Photoprod on Proton.
- Phenomenology for VN SL.
 - VMD Model.
 - Nucleon Formfactor.
- Vector Meson Nucleon SL Puzzle.
 - Perturbative QCD Effect.
 - $SU(3)$: from Omega to Phi.
- J-PARC for J/ψ & ϕ Production at Threshold.
 - Polarization of Quarkonium.
- Plausibility of Heavy $5q$ in GlueX Data & J-PARC Predictions.
 - Quantum Interference.
- Summary.



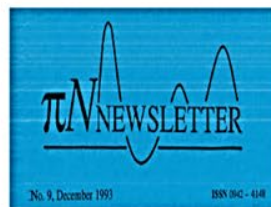


VOLUMES

One
Two
Three
Four
Five
Six
Seven
Eight
Nine
Ten
Eleven
Twelve
Thirteen
Fourteen
Fifteen
Sixteen
SAID Start

Pion-Nucleon Newsletter Archive

<https://gwdac.phys.gwu.edu/analysis/news.html>



I attended

[MENU 2019, Pittsburgh, USA](#)
[MENU 2013, Rome, Italy](#)
[MENU 2010, Williamsburg, USA](#)
[MENU 2007, Jülich, Germany](#)
[MENU 2001, Washington, USA](#)
[MENU 1999, Zuz, Switzerland](#)
[MENU 1997, Vancouver, Canada](#)
[MENU 1995, Tübingen, Germany](#)
[MENU 1993, Boulder, USA](#)



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MENU 2026, Stony Brook U, NY, USA, October 2026

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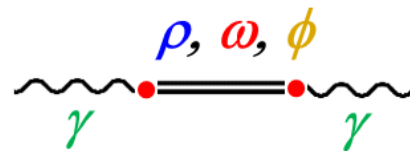
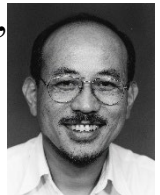
*Once upon a Time, there
was a Vector Meson...*



- There are no *vector meson beams*, so modern experiments using EM & hadronic facilities attempt to access *vector meson – nucleon* interactions via EM $e + p \rightarrow e' + V + p$ & hadronic $\pi^- + p \rightarrow V + n$ production reactions.

- Moreover, vector mesons ρ , ω , & ϕ play central role in *Sakurai's VMD* model, where they account for (virtually admixed) hadronic part of photon by which photon couples to hadronic matter.

J.J. Sakurai, Ann Phys (NY) 11, 1 (1960)



- “*November Revolution*” or discovery of heavy vector meson J/ψ 50 years ago @  & SLAC opened access to new $\bar{c}c$ system.

@ West coast of US J.J. Aubert *et al.* Phys Rev Lett 33, 1404 (1974)

@ East coast of US J.-E. Augustin *et al.* Phys Rev Lett 33, 1406 (1974)



Vector Meson Zoo

- Some **vector mesons** can, compared to other mesons, be measured to very high precision.
- This stems from fact that **vector mesons** have **same** quantum numbers as **photon**.
- Let us focus on **4 vector mesons** from $\bar{q}q$ **nonet** to study **meson photoproduction** @ **threshold** & where data are available.

$$(J^{PC}) = (1^{--})$$

J - spin, **P** - parity
C - charge conjugation



Name



Quark
Content

Γ_{tot}
(MeV)

$\rho^+(770)$

$u\bar{d}$

148

$\rho^0(770)$

$\frac{1}{\sqrt{2}}(u\bar{u} - d\bar{d})$

149

$\omega(782)$

$\frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d})$

8.5

$K^{*+}(892)$

$u\bar{s}$

51

$K^{*0}(892)$

$d\bar{s}$

47

$\phi(1020)$

$s\bar{s}$

4.3

$D^+(1870)$

$c\bar{d}$

6.3×10^{-10}

$D^0(1865)$

$c\bar{u}$

1.6×10^{-9}

$D^{*+}(2010)$

$c\bar{d}$

0.083

$D^{*0}(2007)$

$c\bar{u}$

0.055

$J/\psi(1S)(3097)$

$c\bar{c}$

0.093

$\psi'(2S)(3686)$

$c\bar{c}$

0.284

$Y(1S)(9460)$

$b\bar{b}$

0.052

$T(1S)(?)$

$t\bar{t}$

?

Open Charm

No VMD

Hidden Charm

Bottomium
Toponium

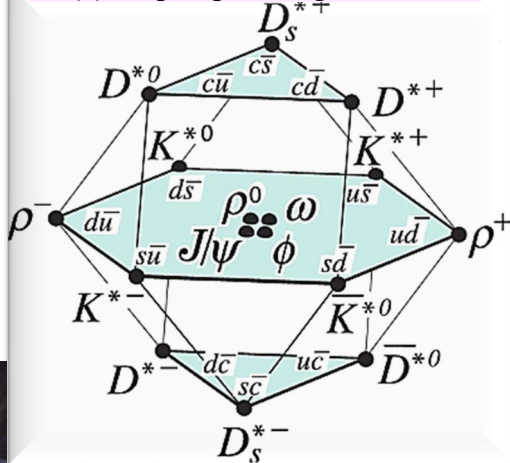
There is
difference
between
1S & 2S states
due to 'zero'
in radial WFs.



gave $t\bar{t}$ pair with rather strong final state interaction.

A. Hayrapetyan *et al*, Rep Prog Phys **88**, 127801 (2025)

SU(4) 15-plet plus singlet structure



J.J. de Swart, Rev Mod Phys **35**, 916 (1963)



It does not exist because large mass & t -quark decay faster than meson formation time.





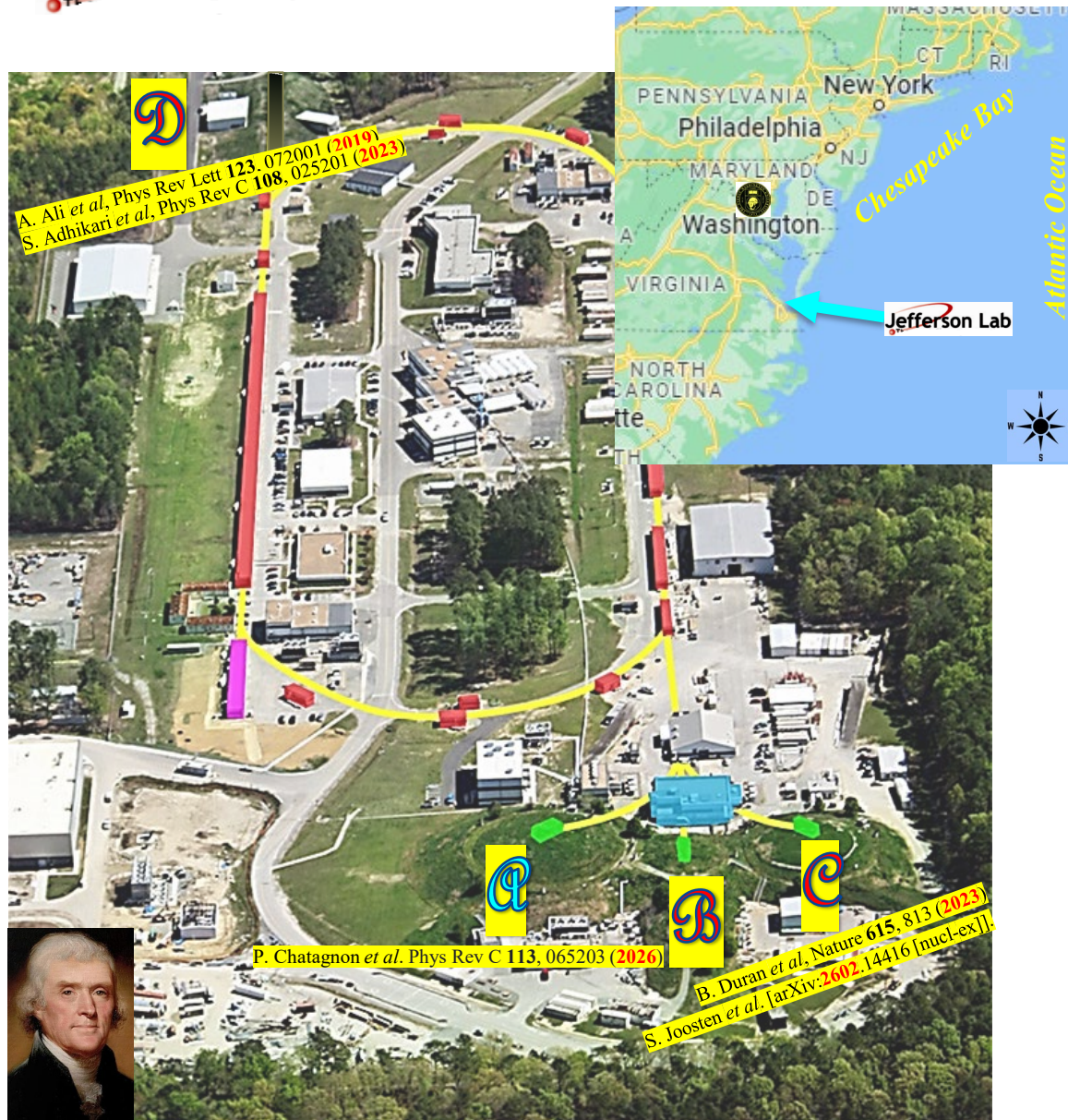
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*J Lab for Threshold J/ψ
Photoproduction on Proton*



Jefferson Lab Continuous Electron Beam Accelerator Facility in 2026



1995 — 2012...

Energy 0.4 — 6.0 GeV

- 200 μA , Polarization 85%
- Simultaneous delivery 3 Halls — A, B, C

- 500+ PhDs completed
- On average 22 US Ph.Ds per year, roughly 25–30% of US Ph.Ds in nuclear physics
- 1530 users in FY16, ~1/3 international from 37 countries

...2016 — ...

Energy 0.4 — 12.0 GeV

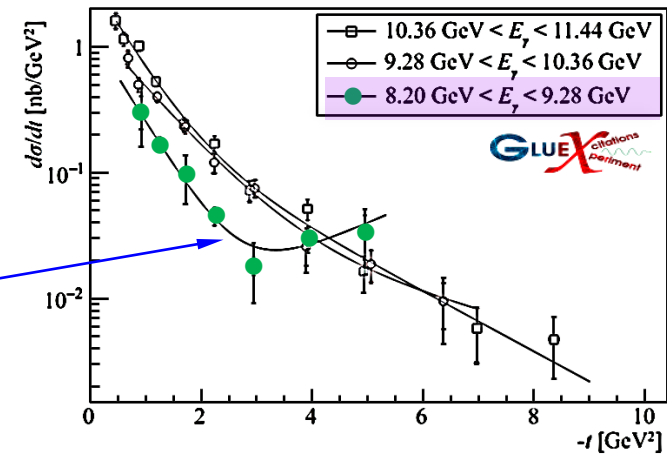
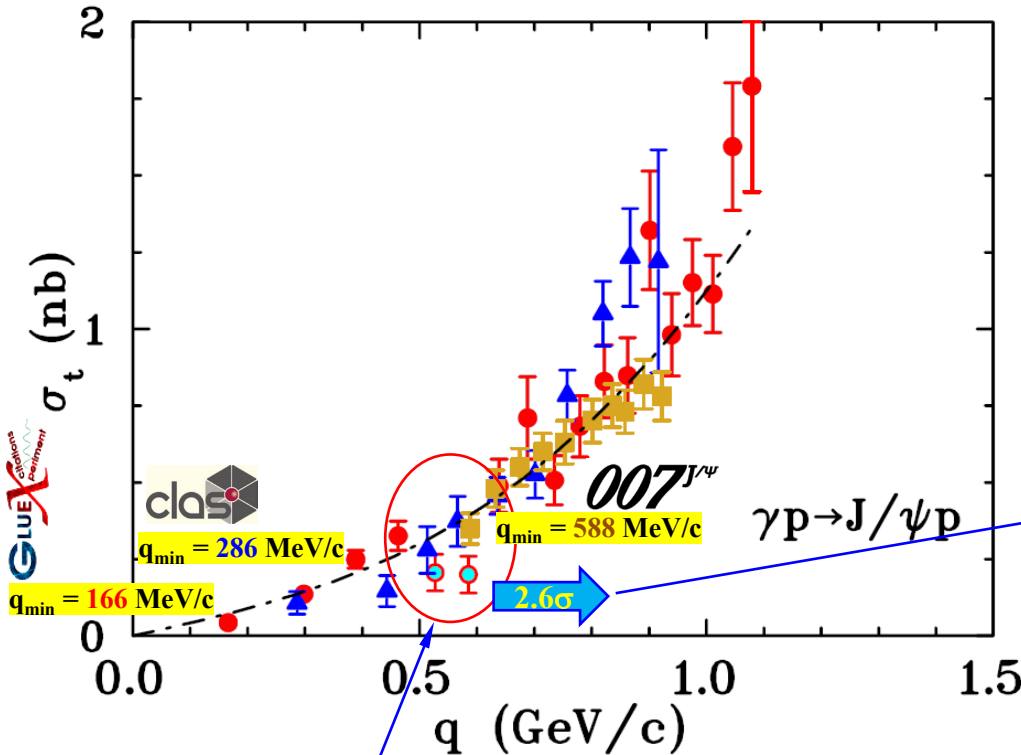
- 150 μA , Polarization 85%
- FY18: First simultaneous delivery to 4 Halls — A, B, C, D

- Jefferson Lab with 12 GeV beam of e^- , has unique opportunity to measure high statistical J/ψ photoprod Xsec @ thr, which is 8.2 GeV.



Jefferson Lab *Total Cross Sections for Vector Meson Photoproduction: Contribution for SL*

IIS, J.K. Ahn, W.J. Briscoe, M.G. Ryskin, & A. Schmidt, Phys Rev D **113**, 114023 (2026)



S. Adhikari *et al*, Phys Rev C **108**, 025201 (2023)

While **007^{J/ψ}** data lacks coverage in **q** to make firm statement about existence of **dip**, more recent **clas** electroproduction data *do not show* evidence of **dip**. Still, **uncertainties are very large** (low statistics) to solve this puzzle.

- Agreement between all three **J/ψ** data sets
 **007^{J/ψ}** 
 shows no indication of systematic differences between methodologies.

- **Two** exponential functions fit Xsec.
- **Second** exponential contribution is most significant in *lowest energy bin*, where slope *changes sign*.





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Phenomenology for Vector Meson-Nucleon Scattering Length



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Vector Meson – Nucleon SL Determination

IIS, D. Epifanov, & L. Pentchev, Phys Rev C **101**, 042201 (2020)
IIS, L. Pentchev, & A.I. Titov, Phys Rev C **101**, 045201 (2020)



- Small **positive** or **negative** VN SL may indicate weakly **repulsive** or **attractive** VN interaction if there is no VN bound state below experimental q_{min} .
- For evaluation of **absolute** value of VN SL , we apply **VMD** approach that links near-thr photoprod X sections of $\gamma p \rightarrow Vp$ & elastic $Vp \rightarrow Vp$

$$\frac{d\sigma_{\gamma p \rightarrow Vp}}{d\Omega} \Big|_{thr} = \frac{q}{k} \frac{1}{64\pi} |T_{\gamma p \rightarrow Vp}|^2 = \frac{q}{k} \cdot \frac{\pi\alpha}{g_V^2} \frac{d\sigma_{Vp \rightarrow Vp}}{d\Omega} \Big|_{thr} = \frac{q}{k} \cdot \frac{\pi\alpha}{g_V^2} |\alpha_{Vp}|^2$$

$q \rightarrow 0$ V CM momentum
 $k = (s - M^2) / 2 s^{1/2}$ Photon CM momentum
 $|T_{\gamma p \rightarrow Vp}|^2$ Invariant amplitude of V photoproduction
 $g_V^2 = \frac{\pi \cdot \alpha^2 \cdot m_V}{3 \cdot \Gamma(V \rightarrow e^+e^-)}$ Fine-structure constant
 α_{Vp} VMD coupling constant, related to VEM decay width $\Gamma(V \rightarrow e^+e^-)$

- Absolute value SL is determined by interplay of **strong** (*hadronic*) & **EM** dynamics as:

$$|\alpha_{VN}|^2 = (h B)^2$$

where **hadronic** component is $h^2 = a$ & linear term **a** came from

$$\sigma_t = a q^2 + b q^3 + c q^4$$

Experiment

pure **EM VMD**-motivated kinematic factor

$$B^2 = \frac{\alpha}{12\pi} \frac{m_V k_{thr}}{\Gamma(V \rightarrow e^+e^-)}$$



- For VN system, to avoid their uncertainties, we do not
 - Determine *sign* of SL ,
 - Separate **Re** & **Im** parts of SL ,
 - Extract *total angular momentum* **1/2** & **3/2** contributions

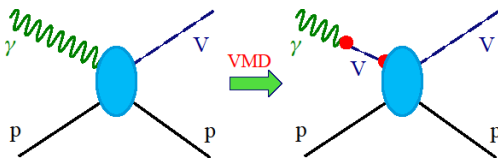




UIN2 Model



VMD for VN Interaction



- pp & ωp SL were determined from photoprod reactions $\gamma p \rightarrow Vp$ with VDM .
Non-perturbative QCD-related approach employing *dressed quarks* & *gluons* as ingredients for $\gamma p \rightarrow Vp$ reaction model is under development in 



- To estimate theoretical uncertainty related to VMD model, one refers to estimation of Xsec of J/ψ photoproduction in *peripheral model* & found strong energy dependence close to threshold because non-diagonal $\gamma p \rightarrow Vp$ & elastic $Vp \rightarrow Vp$ must have larger transfer momenta vs elastic scattering. This results in violation of VMD by factor of **5**.



K.G. Boreskov & B.L. Ioffe, Sov J Nucl Phys **25**, 331 (1977)

- **Color** factor for *hidden charm* is **1/9**, while for *open charm* is **8/9**.



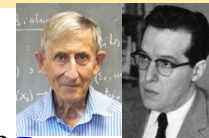
B.Z. Kopeliovich, I. Schmidt, & M. Siddikov, Phys Rev C **95**, 065203 (2017)

- Strong suppression in VN interaction close to thr is observed because of $Q\bar{Q}$ pair in point-like configuration lacks sufficient time to form complete wave function of *vector meson*; that is, proton interacts with "young" (undressed quarks) *vector meson* whose size is smaller than that of "old" one participating in elastic $Vp \rightarrow Vp$ scattering.



E.L. Feinberg, Sov Phys Usp, **23**, 629 (1980)

Courtesy of Misha Ryskin, July 2020



- In recent study, effect of VMD assumption was studied in formalism of *Dyson-Schwinger equations*, which one can consider alternative interpretation of "young age" in connection to QCD.

Y.Z. Xu, S. Chen, Z.Q. Yao, D. Binosi, Z.F. Cui, & C.D. Roberts, Eur Phys J C **81**, 895 (2021)





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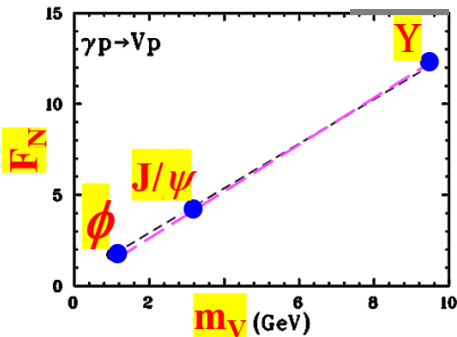
Opportunities are emerging at Brookhaven National Laboratory.

Nucleon Formfactor



Vector Meson SL Accounting Nucleon FF

IIS, J.K. Ahn, W.J. Briscoe, M.G. Ryskin, & A. Schmidt, Phys Rev D **113**, 114023 (2026)



$$F_N(t) = \frac{1}{1 - t/\Lambda^2}$$



Meson	Photoproduction SL (fm)	$-t_{min}$ (GeV ²)	SL/ $F_N(t)$ (fm)	pQCD (fm)	dynSL  (fm)
ϕ	0.063 ± 0.010 [14]	0.50	0.109 ± 0.017	0.065	0.123
J/ψ	$0.00274 \pm 0.00027^{\dagger}$	2.22	0.0113 ± 0.0011	0.0029	0.00634
Υ	0.00051 ± 0.00003 [17]	8.07	0.0063 ± 0.0004	0.00047	0.00196

- **Finally**, recall that actually we deal with $Q\bar{Q}$ -proton interaction & not with elastic $Vp \rightarrow Vp$ scattering.
- Size of this pair, produced by point-like photon, is smaller than normal V size.
- Thus, it is natural to expect smaller Xsec. This “*young effect*” explains relatively small values of **SL** measured in photoprod.

- In photoproduction, $Q\bar{Q}$ pair is produced @ point (locally) by *point-like photon*, & heavy quarks do not have sufficient time to fly away @ distances corresponding to normal size of V wave function.
- **That is**, actually, we deal with small-sized $Q\bar{Q}$ pair-proton interaction & not with normal Vp scattering.
- **On other hand**, within pQCD, corresponding Xsec $\sigma(Q\bar{Q}+p) \propto r^2$, where r is $Q\bar{Q}$ separation.
- Indeed, small size (*young*) colorless object is almost sterile with respect to QCD interaction.
- Therefore, **SL**, ie, Xsec measured in photo(electro)prod, is smaller than that for $Vp \rightarrow Vp$ interaction.
- Recall that, strictly speaking, to measure **SL** of V -proton interaction, we have to consider not V photoprod but V elastic scattering on proton.
- In comparison with elastic process in case of photoprod, we have *three* additional factors that may depend on m_V .
- We have to emphasize that to produce heavy V @ thr, we need to have rather large momentum transferred t .





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Vector Meson Nucleon Scattering Length Puzzle



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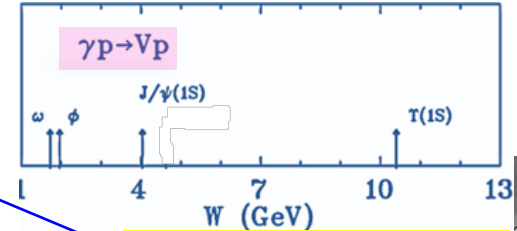


Can Young Hypothesis Explain Vector Meson – Nucleon SL Puzzle?

IIS, J.K. Ahn, W.J. Briscoe, M.G. Ryskin, & A. Schmidt, Phys Rev D **113**, 114023 (2026)

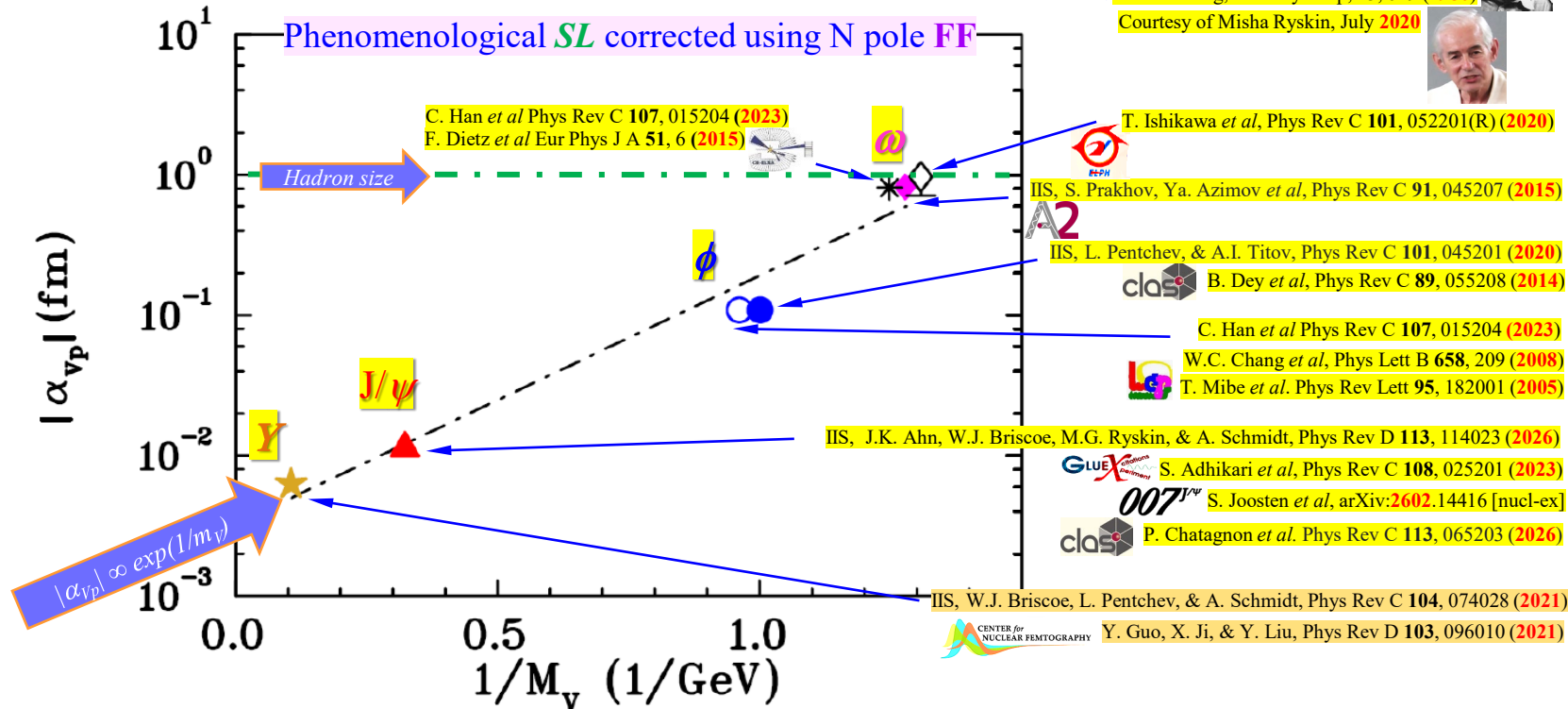
- Due to **small size** of “**young**” V vs “**old**” V , measured & predicted **SL** is very small.
- V created by photon @ threshold then most probably V is not **formed completely** & its radius is smaller than that for normal (“**old**”) V .
- Therefore, one observes stronger suppression for Vp interaction.

$$|\alpha_{\gamma p}| \ll |\alpha_{J/\psi p}| \ll |\alpha_{\phi p}| \ll |\alpha_{\omega p}|$$



E.L. Feinberg, Sov Phys Usp, **23**, 629 (1980)

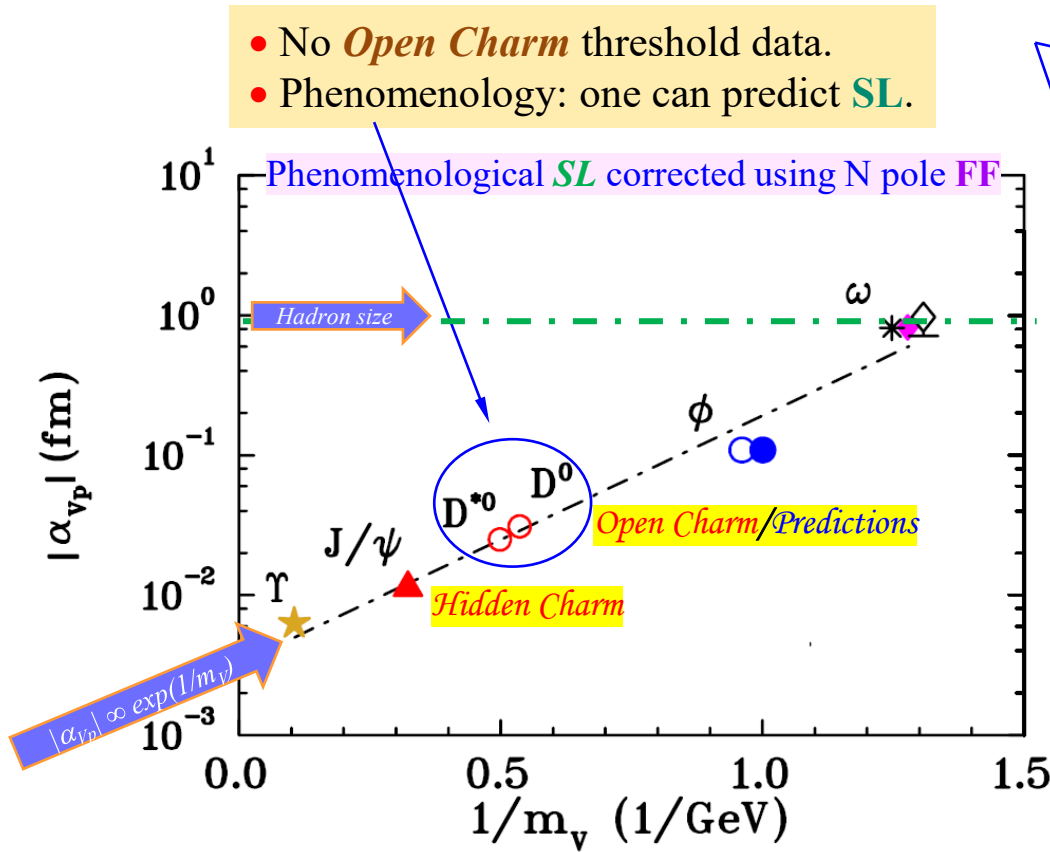
Courtesy of Misha Ryskin, July 2020



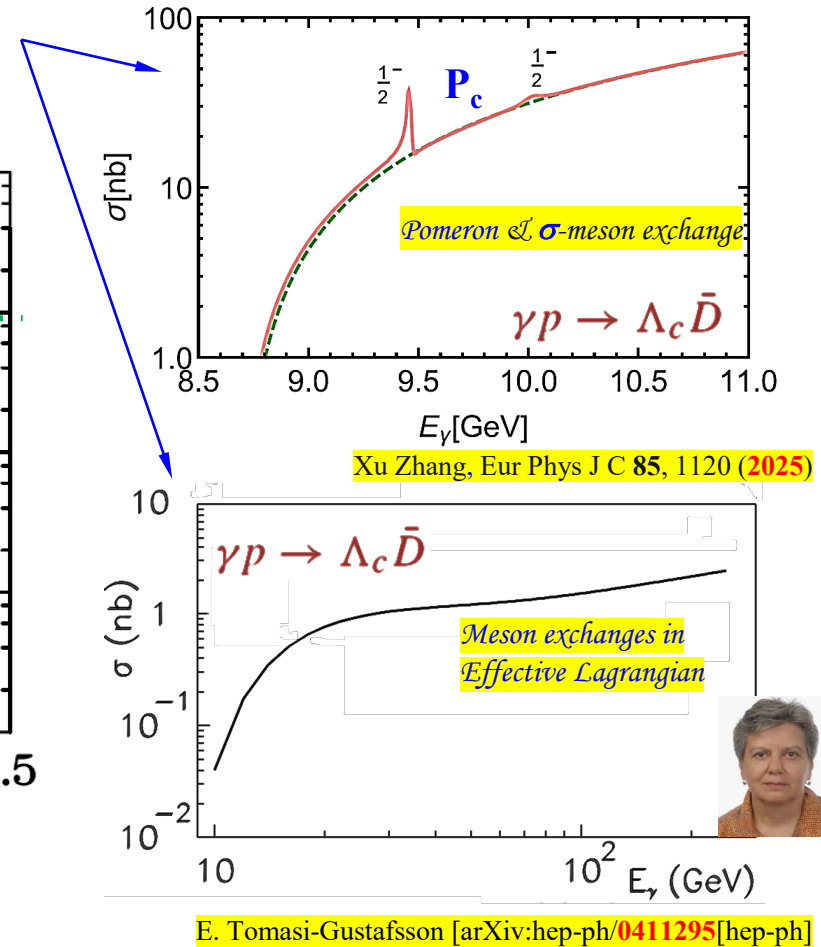
- $p \rightarrow V$ coupling $\bar{q}q$ is proportional to a_s & **separation** of corresponding quarks.
- This **separation** (in zero approximation) is proportional to $1/m_V$.



$$\gamma p \rightarrow \Lambda_c \bar{D} \quad \& \quad \pi^- p \rightarrow \Lambda_c D^-$$



- Problem is "**young effect**". **SL** depends on **Q-Q** separation.
- In the case of **Open Charm**, this separation is driven just by m_Q , while in **V** photoprod it is somewhere between **Vs** size (which is larger than $1/m_Q$) & $1/m_Q$.
- That is, we expect **Open Charm SL** to be smaller than **prediction** coming from this curve (one can consider this prediction as **upper limit**).



- Theory is "blind" @ thr; most couplings are unknown.
- Just exp data will allow us to understand $c\bar{u}$ & qqq interaction dynamics.





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Perturbative QCD Effect



- Our analysis shows almost linear (on exponential scale) increase in $|\alpha_{Vp}| \propto \exp(1/m_V)$ with increasing $1/m_V$.
- This is interesting observation; however, behavior *does not satisfy expected asymptotic*

$$\alpha_{Vp} \rightarrow 0 \text{ as } m_V \rightarrow \infty.$$

- In fact, in pQCD, $p \rightarrow V$ coupling is proportional to strong coupling α_s & separation of corresponding quarks.
This separation (in zero approximation) is proportional to $1/m_V$, or $1/m_Q$, where m_Q is current quark mass.
- Taking current quark masses  as $m_s = 0.1$ GeV, $m_c = 1.3$ GeV, & $m_b = 4.2$ GeV, along with constant $\Lambda = 350$ MeV, & inserting

$$\alpha_{Vp} = 1/30 \cdot 0.197 [\text{fm} \cdot \text{GeV}] \alpha_s(m_Q) / m_Q$$

with one-loop $\alpha_s = (4\pi/b_0) / \ln(m_Q^2/\Lambda^2)$,

but if $\alpha_s > 1$, then $\alpha_s = 1$ (ie, α_s is frozen @ 1; & b_0 is referred to as one-loop β -function coefficient $b_0 = 8.33$ for 4 light quarks: u, d, s, & c).

Meson	Photoproduction SL (fm)	SL/ $F_N(t)$ [7] (fm)	pQCD [7] (fm)	dynSL  (fm)	CC  (fm)
ϕ	0.063 ± 0.010 [17]	0.109 ± 0.017	0.065	0.123	
J/ψ	0.00274 ± 0.00027 [7]	0.0113 ± 0.0011	0.0029	0.00634	0.0002-0.0030
Υ	0.00051 ± 0.00003 [18]	0.0063 ± 0.0004	0.00047	0.00196	

- Of course, expression is not real *perturbative QCD* calculations. This is just *naive estimate*. However, it demonstrates that observed SLs are consistent with *perturbative QCD* & account for suppression due to *young* effect.

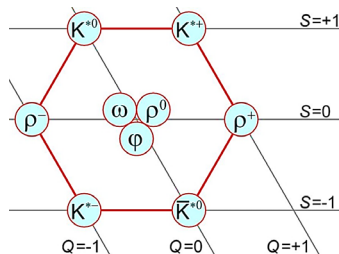
- Recall that aim of our project is not to build model that describes data, but phenomenological analysis. (Model(s) & corresponding theoretical uncertainties can be found, eg, in  & )





$SU(3)$: from Omega to Phi





$SU(3)_F$ for VN SL

IIS, J.K. Ahn, W.J. Briscoe, M.G. Ryskin, & A. Schmidt, Phys Rev D **113**, 114023 (2026)

Vector-meson nonet is $\rho(770)$, $K^*(892)$, $\omega(782)$, $\phi(1020)$
with multiplicities: $3\rho + 4K^* + 1\omega + 1\phi = 9$

- Actually, paper by Titov *et al.* gives relationship between SL s of ϕN & ωN using $SU(3)_F$ symmetry:

$$|\alpha_{\phi N}| = \epsilon |\alpha_{\omega N}|$$

where

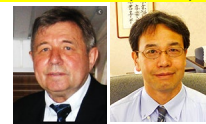
$$\epsilon \equiv -\text{tg}(\Delta\theta_V) \text{ \& } \Delta\theta_V \simeq 3.7^\circ$$

represents **deviation of ϕ - ω mixing angle** from **ideal mixing angle**.

(Vector mixing angle $\theta_V = 36.5^\circ$ is very close to **ideal mixing angle**. )

A.I. Titov, T. Nakano, S. Date, & Y. Ohashi, Phys. Rev. C **76**, 048202 (2007).

This relation assumes that SL originates from *light* (u, d) quarks only, most likely from nucleon resonances.



- Ratio of our phenomenological SL determination

$$|\alpha_{\omega N}| = 0.82 \text{ fm}$$

IIS, S. Prakhov, Ya. Azimov *et al*, Phys Rev C **91**, 045207 (2015)

$$|\alpha_{\phi N}| = 0.063 \text{ fm}$$

IIS, L. Pentchev, & A.I. Titov, Phys Rev C **101**, 045201 (2020)

corresponds to $\Delta\theta_V \simeq 4.4^\circ$

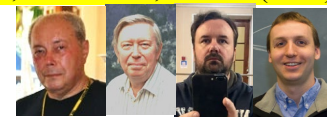
- In $SU(3)_F$, there should be similar relation for $|\alpha_{\phi N}|$ with $|\alpha_{\omega N}|$ & $|\alpha_{\phi N}|$ with $|\alpha_{\rho N}|$.

However, for ρ , it may be partly spoiled by large ρ width.

Besides this, in $\rho\rho$ case, result may be affected by **isobars** ($I = 3/2$).

IIS, E. L. Isupov, V. Mokeev, & A. Schmidt, Rev. D **112**, 114045 (2025)

That is likely why $|\alpha_{\omega N}| \simeq 4 |\alpha_{\rho N}|$, as was reported recently.





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J-PARC for J/ψ & ϕ

Production at Threshold





K10 and Hadron Experimental Facility Extension

• K10: K^- & $\bar{p}$ beam

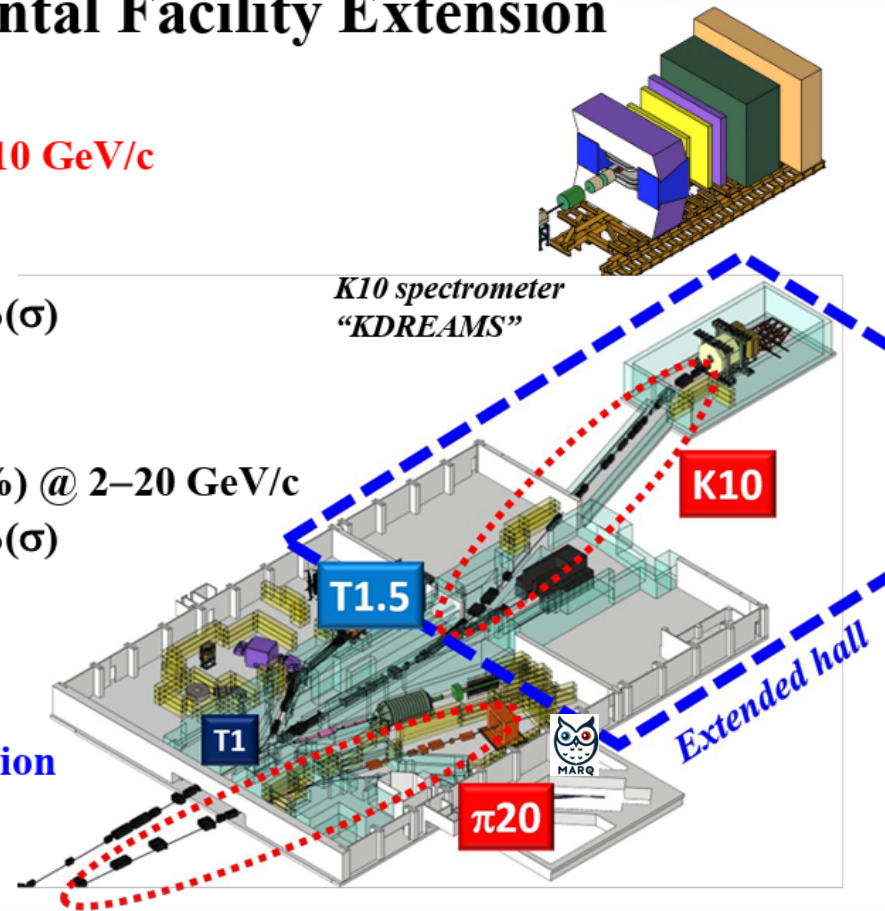
- Intensity: $>10^6$ /spill for $K^-/\bar{p}$ @ 2–10 GeV/c
- Purity: $K/\pi \sim 1/2$, $\bar{p}/\pi \sim 2/1$
 - Particle separation by RF separator
- Momentum resolution: $\Delta p/p = 0.1\%(\sigma)$

• $\pi 20$: π^- beam (Unseparated)

- Intensity: $>10^7$ /spill π^- (K^- , $\bar{p}$: 1–2%) @ 2–20 GeV/c
- Momentum resolution: $\Delta p/p = 0.1\%(\sigma)$

* High-momentum hadron beams

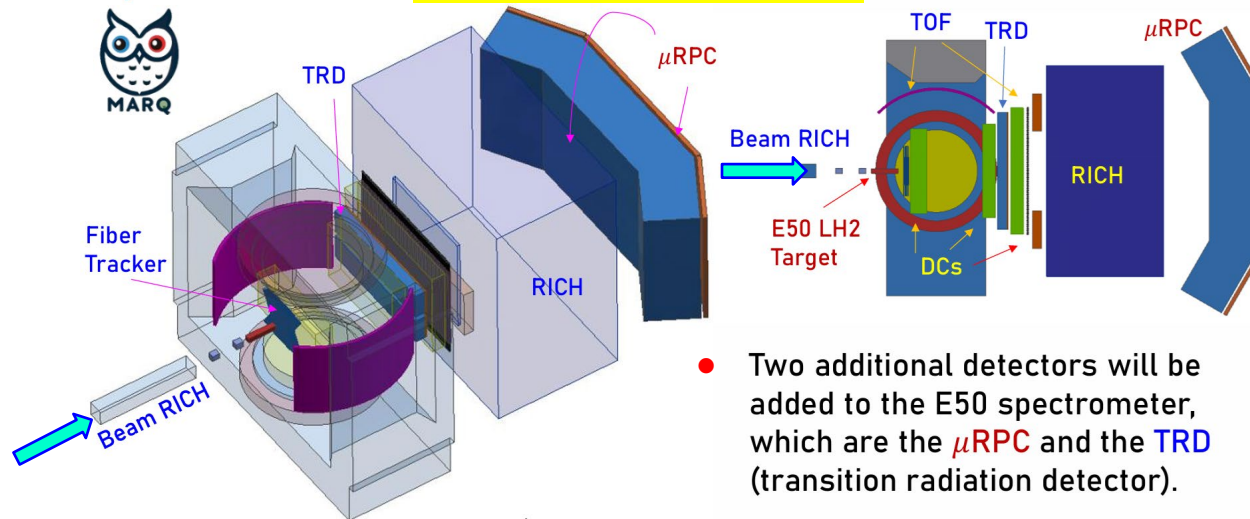
- Unique in the world
- Charm and strange hadron production
- High-intensity: Systematic study





- New high-energy $\pi 20$ & K10 beamline, utilized by P111 experiment

Spectrometer (MARQ & Dilepton Det.)



- For detection of the $J/\psi \rightarrow e^+ e^-$ decay, we also consider alternative detector candidates such as a large array of the forward EM calorimeter and/or preshower sampling calorimeters in the magnet.

- Theoretical predictions for J/ψ production Xsec span wide range, from **1 pb** to **50 nb**, depending on interpretations of these limits.
- If Xsec reaches approximately **4 nb @ $p = 9.5$ GeV/c**, Anticipated J/ψ yield in momentum range **$p = 8.2 - 11.0$ GeV/c** is estimated to be **10^4 events**.

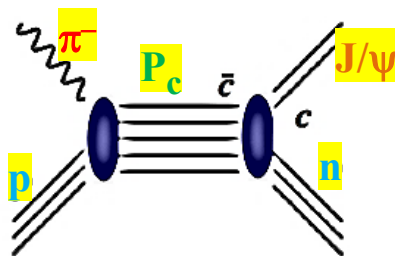


Courtesy of Sun Young Ryu, September 2025

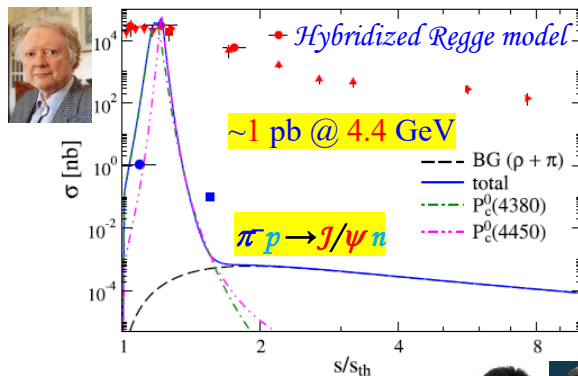


- Key distinction of $\pi^- p \rightarrow J/\psi n$ reaction @ J-PARC is that, unlike photon-induced reactions - where photon creates quark pair @ interaction point, as seen in GLUEX , 007^{TM} , & CLAS - pion-induced process involves *two quarks* that are already separated from beginning.
- We would add, however, that in s-channel resonance, $\bar{c}c$ separation may be different from that in J/ψ photoproduction.

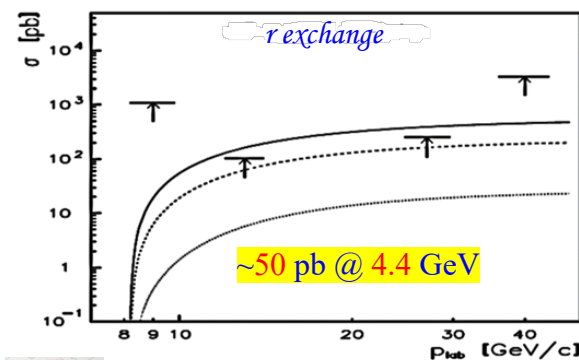
Theory for J/ψ Production using Pion Beam



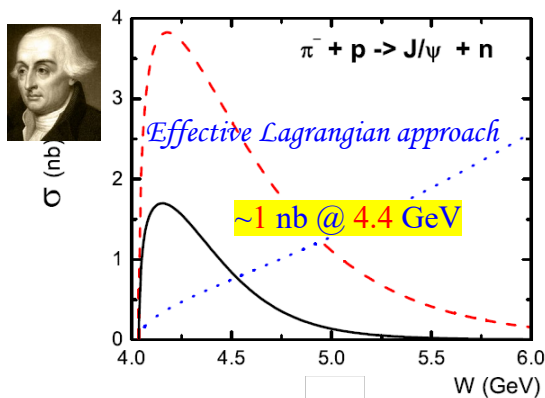
- Looking for bumps via *constructive interference* between **s-channel P_c Res** & **non-resonant background**.



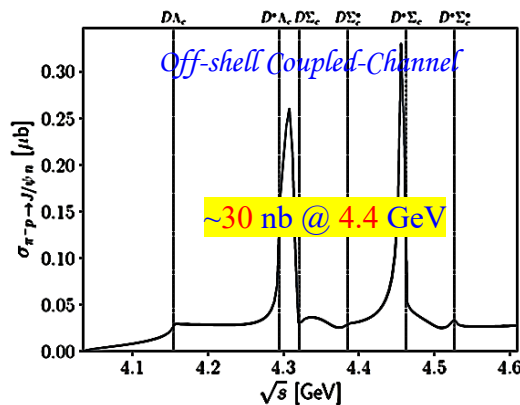
S.H. Kim, H.C. Kim, & A. Hosaka,
Phys Lett B 763, 358 (2016)



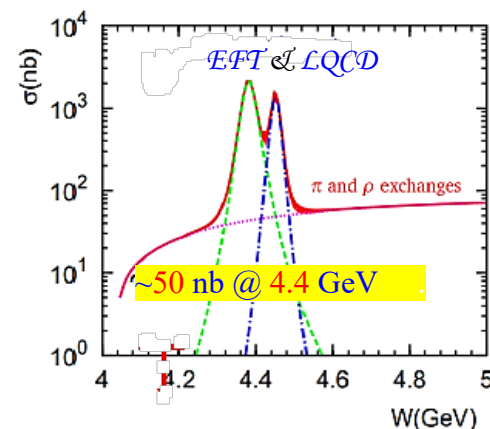
A. Sibirtsev & K. Tsushima,
arXiv:nucl-th/9810029



J.J. Wu & T.S.H. Lee,
Phys Rev C 88, 015205 (2013)



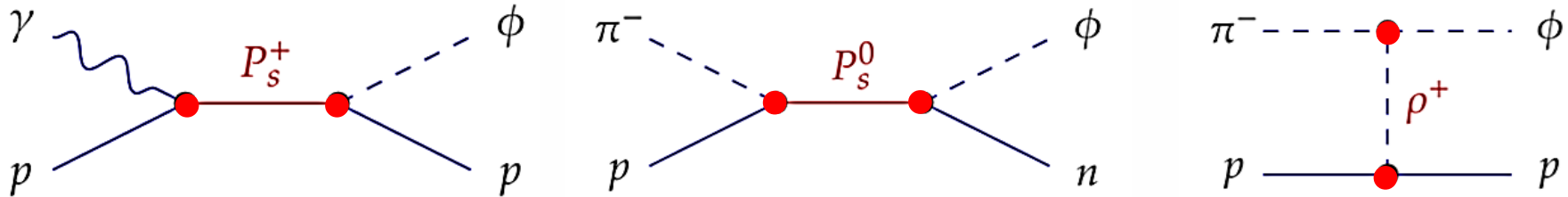
S. Clymton, S.Y. Ryu, J.K. Ahn, &
H.C. Kim, arXiv:2605.28285 [hep-ph]



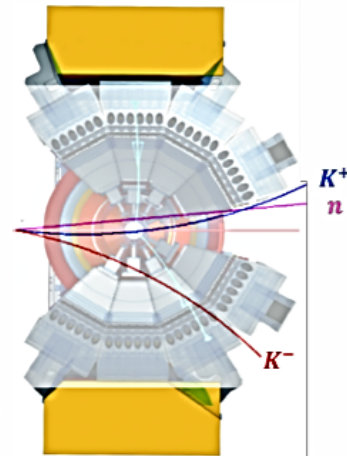
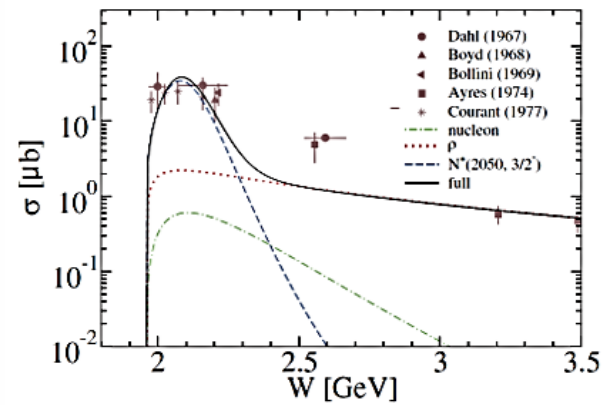
Q.F. Lue, X.Y. Wang, J.J. Xie, X.R. Chen, &
Y.B. Dong, Phys Rev D 93, 034009 (2016)



$P_{s\bar{s}}$ Search via Pion-induced Reactions



- While t -channel dominates in $\gamma p \rightarrow \phi p$, s channel dominates in $\pi^- p \rightarrow \phi n$.
- The $\pi^- p$ reaction probes a $P_{s\bar{s}}^0$, an isospin-doublet member with $P_{s\bar{s}}^+$.
- The J-PARC E95 will measure cross sections for $\pi^- p \rightarrow \phi n$ at momenta from 1.6 to 2.4 GeV/c to explore N^* and possible $P_{s\bar{s}}$ coupled to ϕN .^a



- Theoretical calculation supports an s -channel dominance below 2.2 GeV/c (Sangho Kim).

^a E95 Proposal, J-PARC, 2024.



September 8, 2026 Slide 9

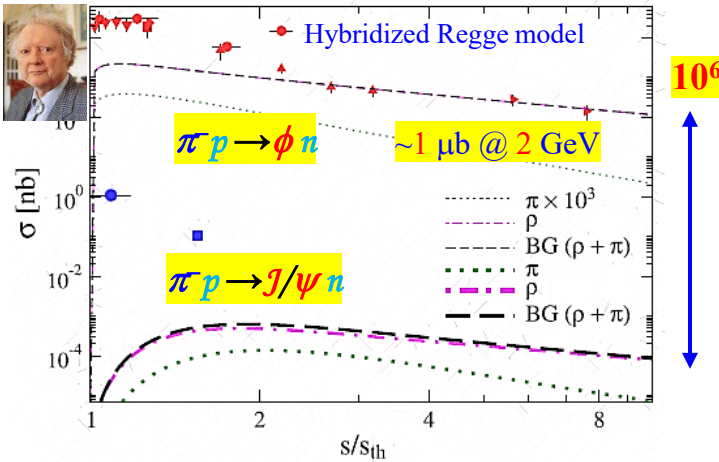


Courtesy of Jung Keun Ahn, Sept. 2026

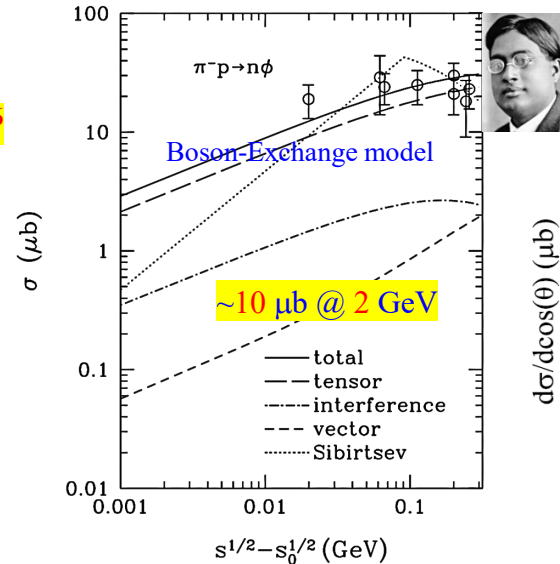


Theory for ϕ Production using Pion Beam

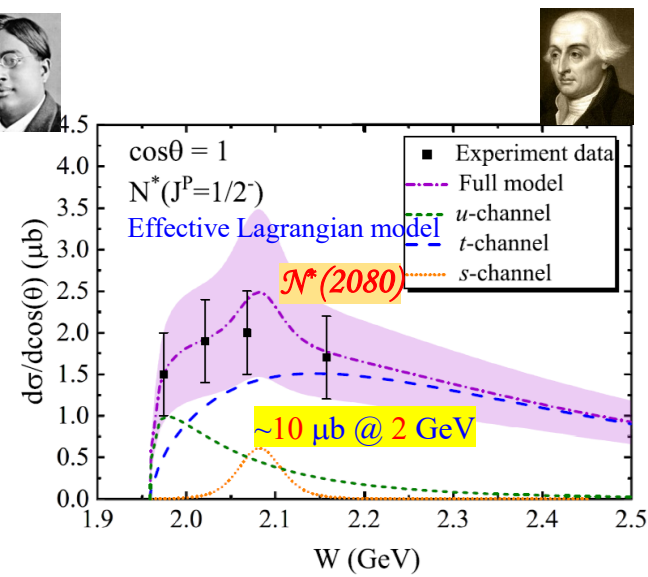
No thr data



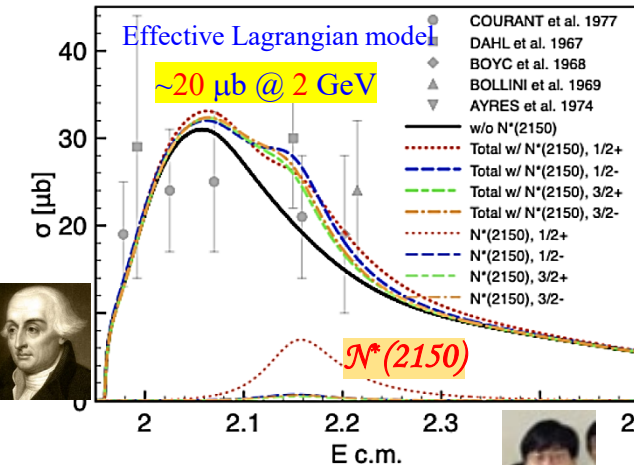
S.H. Kim, H.C. Kim, & A. Hosaka,
Phys Lett B 763, 358 (2016)



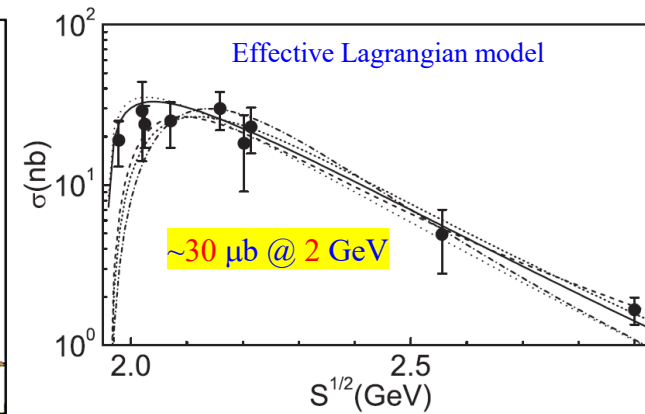
X.Y. Wang, H.F. Zhou, & X. Liu,
Phys Rev D 110, 014026 (2024).



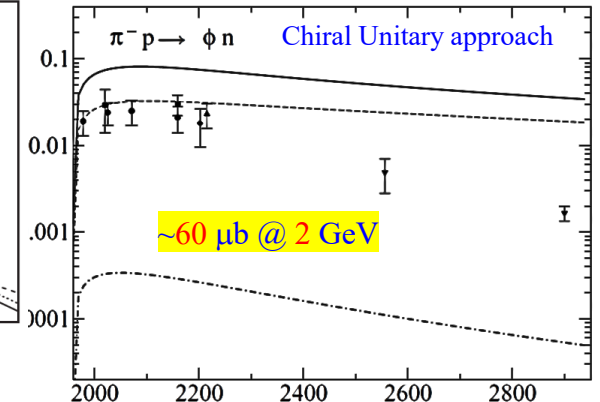
W.S. Chung, G.Q. Li, & C.M. Ko,
Phys Lett B 401, 1 (1997)



D. Lee, S.-Nam, & J. K. Ahn,
New Phys: Sae Mulli, 76, 119 (2026)



J.J. Xie, B.S. Zou, & H.C. Chiang,
Phys Rev C 77, 015206 (2008).



M. Doering, E. Oset, & B.S. Zou,
Phys Rev C 78, 025207 (2008)



10/20/2026

MENU 2026, Stony Brook U, NY, USA, October 2026

Igor Strakovsky 27





Discovery Park

Opportunities are emerging at Brookhaven National Laboratory.

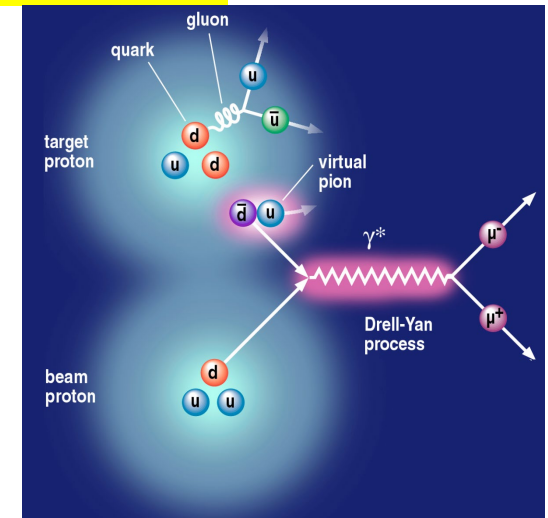
Polarization of Quarkonium



J-PARC for $\pi p \rightarrow J/\psi n \rightarrow (e^+e^-) n$

- Crucial point for $\pi p \rightarrow J/\psi n$ case (as J-PARC will be measured) is that *photon* creates/produces quark pair @ POINT (@ ~~GLUEX~~) while in *pion* case, we deal with two quarks separated from one another @ beginning.

- Depending on production mechanism for J/ψ , polarization of J/ψ could change. For example, some production mechanisms are expected to produce largely unpolarized J/ψ (such as inclusive production), while other mechanisms can produce polarized J/ψ (such as exclusive production or thr production). For example, when NuSea Collaboration measured polarization of J/ψ produced in pA inclusive production @ 800 GeV beam energy, they found that J/ψ is somewhat polarized, but much less polarized than Drell-Yan di-leptons.



C.N. Brown *et al.* Phys Rev Lett **86**, 2529 (2001)

T.H. Chang *et al.* Phys Rev Lett **91**, 211801 (2003)



Jen-Chieh Peng: ``Polarization of quarkonium remains mystery''.



J/ψ polarization matrix is measured via angular distribution of electrons in $J/\psi \rightarrow e^+e^-$ decay.



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Plausibility of Heavy Pentaquark in GlueX Data & J-PARC Predictions



Θ^+ : Debunked or Vindicated



Two possible scenarios:

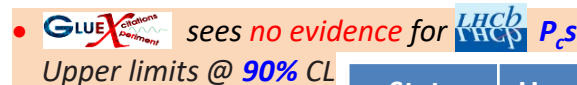
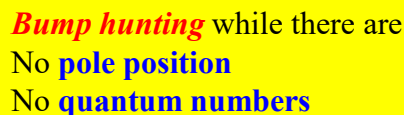
- Dramatic comeback with new experimental attempts using K^+ (J-PARC) and K_L (JLab) beams?
- Resurrected and executed twice?

Courtesy of Jung Keun Ahn, Sept. 2026

R. Aaij *et al*, Phys Rev Lett **122**, 222001 (2019)

GLUEX
excitations
experiment

A. Ali *et al*, Phys Rev Lett **123**, 072001 (2019)

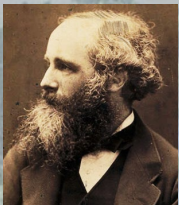


State	M (GeV)	$\Gamma[P_c \rightarrow J/\psi p]$ (MeV)	BR	Significance
$P_c(4312)^+$	$4311.9 \pm 0.7^{+6.8}_{-0.6}$	$9.8 \pm 2.7^{+3.7}_{-4.5}$	$0.3 \pm 0.07^{+0.34}_{-0.09}$	7.3σ
$P_c(4440)^+$	$4440.3 \pm 1.3^{+4.1}_{-4.7}$	$20.6 \pm 4.9^{+8.7}_{-10.1}$	$1.1 \pm 0.33^{+0.22}_{-0.10}$	5.4σ
$P_c(4457)^+$	$4457.3 \pm 0.6^{+4.1}_{-1.7}$	$6.4 \pm 2.0^{+5.7}_{-1.9}$	$0.53 \pm 0.16^{+0.15}_{-0.13}$	5.4σ

State	Upper Limit (%)
P _c (4312)	4.6
P _c (4440)	2.3
P _c (4457)	3.8

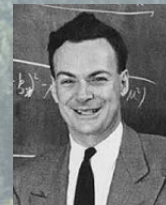


Quantum Interference



*When looking at **Maxwell** equations,
it is hard to imagine how beautiful the **rainbow** is.*

Richard Feynman



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Similar may be said about **Quantum Interference**.

*Everybody knows that the interference does exist.
But it is not always easy to imagine
how it will work in a particular case.*

Yakov Azimov

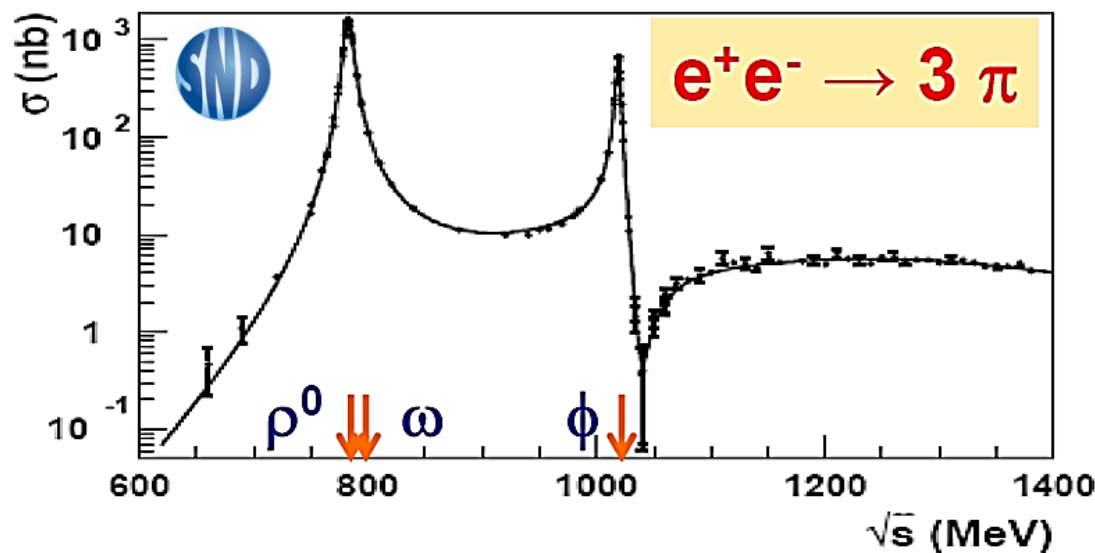
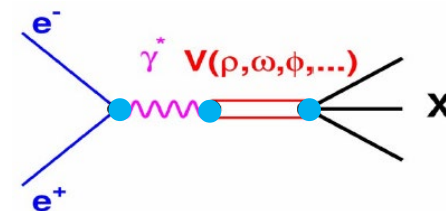


PDG $\Gamma(\rho^0) = 149.4 \text{ MeV}$; $\Gamma(\omega) = 8.5 \text{ MeV}$; $\Gamma(\phi) = 4.3 \text{ MeV}$

$\Gamma(\rho^0 \rightarrow 3\pi) = 0.015 \text{ MeV}$ Isospin violated

$\Gamma(\omega \rightarrow 3\pi) = 7.58 \text{ MeV}$

$\Gamma(\phi \rightarrow 3\pi) = 0.65 \text{ MeV}$ Zweig rule violated



M. Achasov, Nucl Phys B Proc Suppl 162, 114 (2006)

- Bkg near ϕ changes slowly



nearly standard **interference curve**,
instead of ϕ -peak:

both bump & dip,

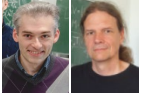
each has form different from BW;

max/min different from ϕ -mass ρ .



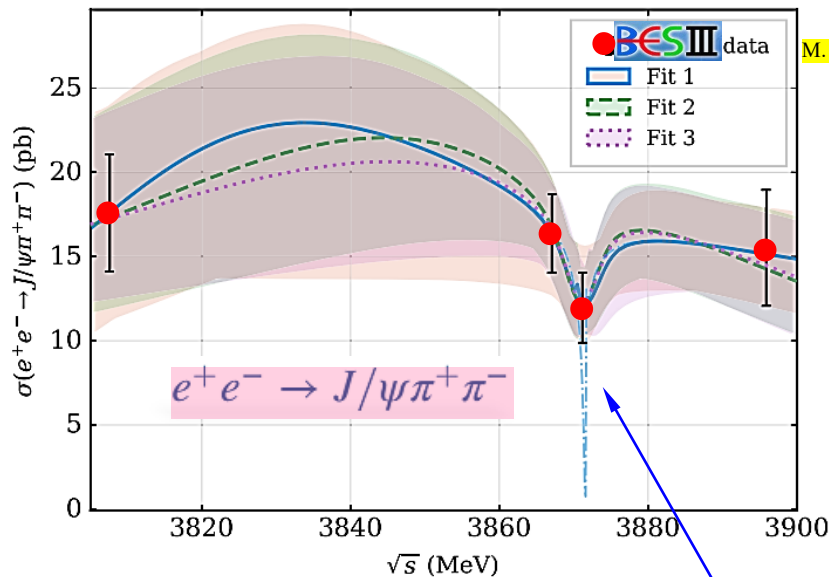
- ρ -contribution here deforms ω -tails.

- Curve is fit with ω , ϕ , ρ , ω' , & ω'' .

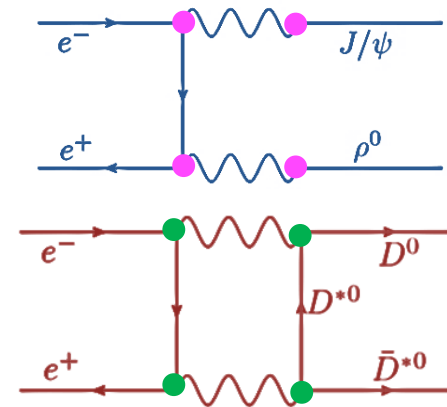


• How does X(3872) show up in e^+e^- collisions.

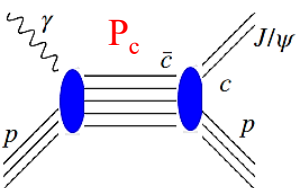
- We demonstrate that the dip observed near the total energy of 3872 MeV in the recent cross section data from the BESIII Collaboration for $e^+e^- \rightarrow J/\psi\pi^+\pi^-$ admits a natural explanation as a coupled-channel effect: it is a consequence of unitarity and a strong S -wave $D\bar{D}^*$ attraction that generates the state X(3872). We anticipate the appearance of a similar dip in the $e^+e^- \rightarrow J/\psi\pi^+\pi^-\pi^0$ final state near the $D^*\bar{D}^*$ threshold driven by the same general mechanism, then to be interpreted as a signature of the predicted spin-2 partner of the X(3872).



M. Ablikim *et al*, Phys Rev D 107, 032007 (2023)



- Effect is small, but visible & more *statistics* is in order.



Recipe for Possible Interpretation of Dip

IIS, W.J. Briscoe, E. Chudakov, I. Larin, L. Pentchev, A. Schmidt, & R.L. Workman, Phys Rev C **108**, 015202 (2023)

- Experimental total Xsec of inelastic binary reaction: $\sigma_t = \int_0^{2\pi} \int_0^\pi \frac{d\sigma}{d\Omega} \sin\theta d\theta d\phi$

Photon CM momentum

J/ψ polar production angle

J/ψ azimuthal production angle

- Phenomenological total Xsec: $\sigma_t = \frac{\pi}{4k^2} \sum_{J=0}^{\infty} (2J+1) |f|^2$

Using Landau-Livshitz normalization

Total angular momentum
(2J+1) = 1 for S-wave
= 3 for P-wave

- Partial Amplitude: $f = b + R \cdot \exp(2i\alpha)$

There is 1 free parameter for interference α

Relative phase shift

It comes from fit of total Xsec

- Non-Res:

$$b = \sqrt{Aq + Bq^3}$$

V CM momentum

There are 2 free parameters for background A & B

IIS, L. Pentchev, & A.I. Titov, Phys Rev C **101**, 045201 (2020)

- Relativistic BW:

$$R = \frac{2\Gamma M}{[(M)^2 - s] - i\Gamma M} X$$

Energy independent Width (P_c is too narrow)

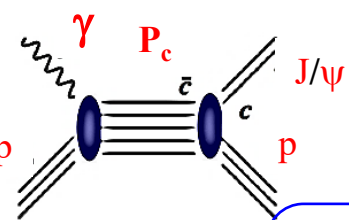
Mass

- Partial Width:

$$X = \frac{\sqrt{\Gamma(\gamma + p) \Gamma(J/\psi + p)}}{\Gamma} = \sqrt{X(\gamma + p) X(J/\psi + p)}$$

Partial decay Widths of
 $P_c \rightarrow \gamma p$ & $P_c \rightarrow J/\psi p$.

There are 3 free parameters for resonance M , Γ , & X



Alternative Solution for **GLUEX** Data

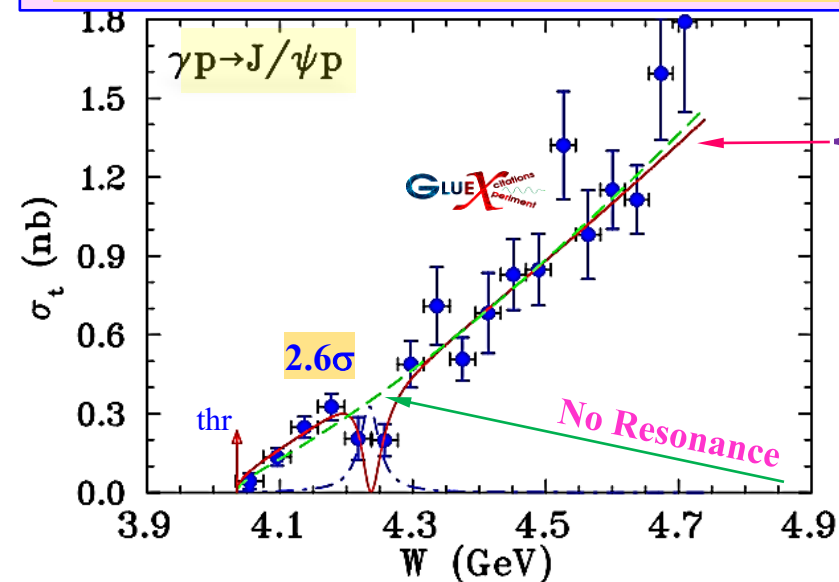
S. Adhikari *et al*, Phys Rev C **108**, 025201 (2023)

IIS, W.J. Briscoe, E. Chudakov, I. Larin, L. Pentchev, A. Schmidt, & R.L. Workman, Phys Rev C **108**, 015202 (2023)

- We suggested to apply *rearrangement interference* for revealing *faint* resonance signals (*amplification* by *interference* with *strong* background signal).
- Relative phase α leads to *constructive* (*bump*) or *destructive* (*dip*) interference for particular **PW**.

$$f = b + R \cdot \exp(2i\alpha)$$

2016–2018 data: $2270 \pm 58 \text{ } \gamma p \rightarrow J/\psi p \rightarrow e^+ e^- p$ & 320 pb^{-1}



Resonance: $\chi^2/\text{ndf} = 11.99/12 = 1.00$

$M = 4235 \pm 8 \text{ MeV}$

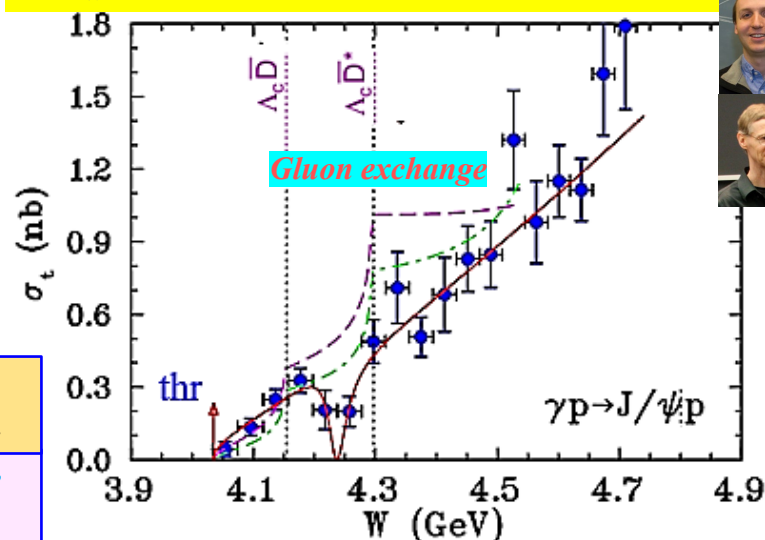
$\Gamma = 35.4 \pm 8.2 \text{ MeV}$

$X = 0.023 \pm 0.005$

$\alpha = 40.8 \pm 5.7 \text{ deg}$

Resolution $\sim 6 \text{ MeV}$

- *Cusp* effect is visible & in agreement with **GLUEX**



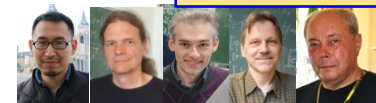
- Effect of *charm* exchange is smaller than *gluon* exchange.
- *Gluon* contribution can be strongly *suppressed* due to “*young*” effect.

- Interference between *open charm* & *gluon exchange* may produce *dip*, but there is room for *resonance*.

Meng-Lin Du, V. Baru, Feng-Kun Guo, Ch. Hanhart, U.-G. Meissner, A. Nefediev, & IIS, Eur Phys J C **80**, 1053 (2020)

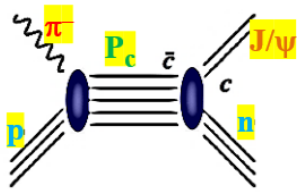
MENU 2026, Stony Brook U, NY, USA, October 2026

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10/20/2026





$$\pi^- p \rightarrow P_{cc} \rightarrow J/\psi n$$

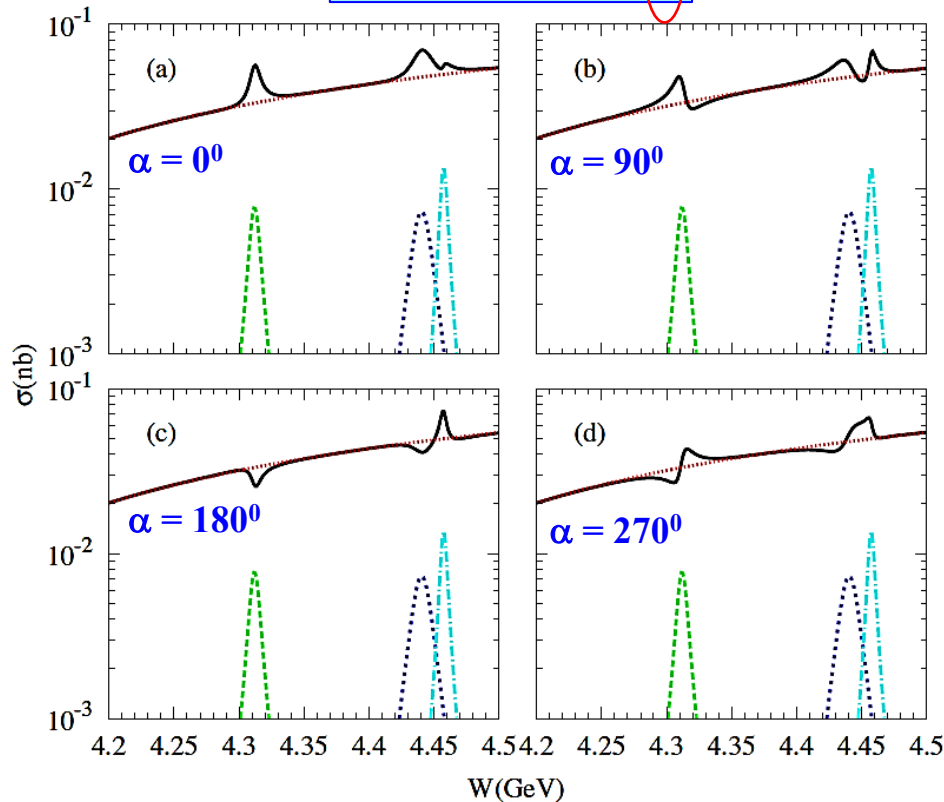
Q.F. Lue, X.Y. Wang, J.J. Xie, X.R. Chen, & Y.B. Dong, Phys Rev D **93**, 034009 (2016)

Qi-Fang Lue, Xurong Chen, Yu-Bing Dong, IIS, Xiao-Yun Wang, & Ju-Jun Xie,

arXiv:2609.23300 [hep-ph]



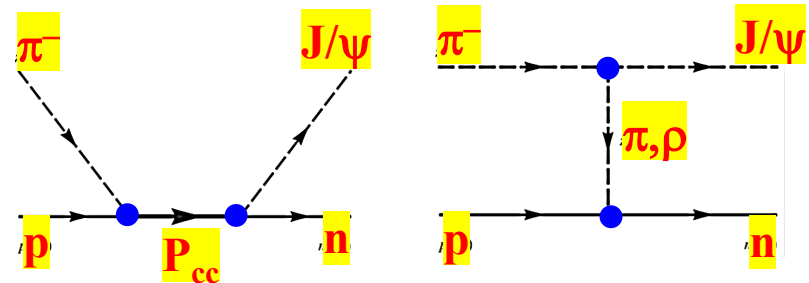
$$f = b + R \cdot \exp(2i\alpha)$$



In inelastic reaction:

constructive interference can give **bump**
destructive interference can give **dip**.

- There are no threshold data.
- Using *effective Lagrangian* approach, one constructs scattering amplitudes for $J^P = 1/2^-$ & $3/2^-$ P_{cc} states under two spin-parity scenarios, with background dominated by t -channel ρ -meson exchange.





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Summary



SUMMARY

- “*Young*” **V** hypothesis may explain fact that obtained **SL** value for ϕ -p, compared to typical hadron size of **1 fm**, indicates that **proton** is more transparent for ϕ -meson compared to ω -meson & is much more transparent for **J/ψ**-meson.

$$|\alpha_{\gamma p}| \ll |\alpha_{J/\psi p}| \ll |\alpha_{\phi p}| \ll |\alpha_{\omega p}|$$

- Furthermore, **pQCD** predictions support phenomenological determination of heavy vector meson-nucleon scattering lengths.
- **J-PARC** is able to measure $\pi p \rightarrow \phi n$ **E95** & $\pi p \rightarrow J/\psi n$ **P111** @ thresholds, which are free from **VMD**, which is important input to phenomenology (**PWA**).
- Upcoming **J-PARC** threshold measurements of reaction $\pi p \rightarrow J/\psi n \rightarrow (l^+ l^-) n$ will help to evaluate possible role of heavy pentaquark, **P_c**, states in low-energy **J/ψ** production & effects caused by nucleon **FFs**.
- @ thr, proton FF should reveal itself.
However, if process goes via some resonance/pentaquark, there slightly different FF.
- **Jefferson Lab** further studies on both *nucleons* & *nuclei* **SRC** in *heavy V* photo- & *electro-production* **RGA** & **RGK** will significantly extend our knowledge of *gluonic* structure of nuclear matter.
-  &  ability allows us to understand dynamics of $\bar{s}s$ & $\bar{c}c$ & $b\bar{b}$ production @ threshold.

- *Polarized measurements* are important contribution to model-independent **PWA**.





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Backup



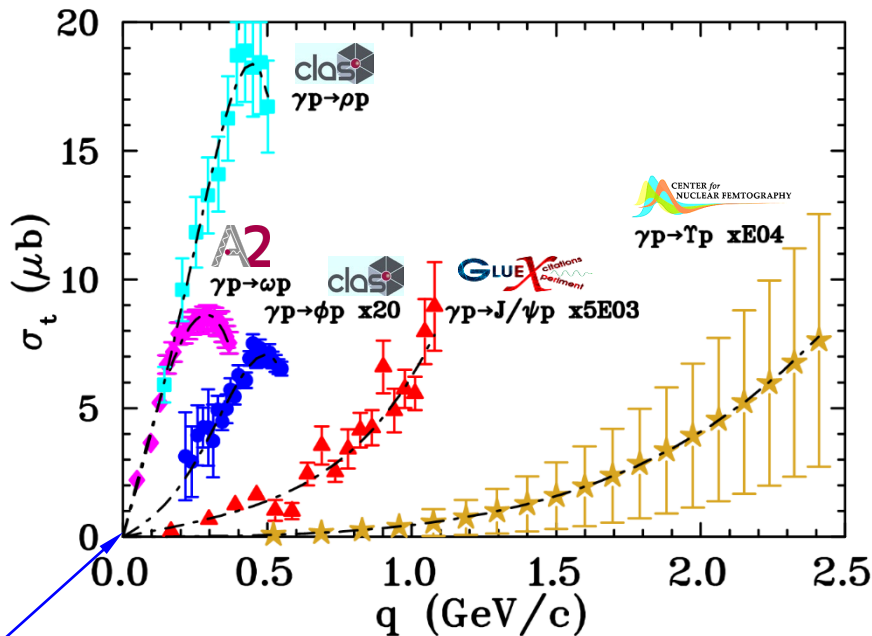
Total Cross Sections for Vector Meson Photoproduction off Proton

- Traditionally, σ_t behavior of near-threshold binary *inelastic* reaction

$$m_a + M_b < m_c + M_d$$

is described as series of *odd* powers in q (*even* powers in case of *elastic*).

$$\sigma_t = a q + b q^3 + c q^5$$



- Our *assumption* is that there are no *VN bound states* below experimental q_{min}

- Linear* term is determined by two independent *S-waves* only with total spin $1/2$ &/or $3/2$.
- Contributions to *cubic* term come from both *P-wave* amplitudes & *W* dependence of *S-wave* amplitudes,
- Fifth-order* term arises from *D-waves* & *W* dependencies of *S-* & *P-waves*.

ω	A2	$a = (4.42 \pm 0.14) \times 10^{-2} \mu\text{b}/(\text{MeV}/c)$ IIS, S. Prakhov, Ya. Azimov <i>et al</i> , Phys Rev C 91 , 045207 (2015)
ρ^0	clas	$a = (3.99 \pm 0.52) \times 10^{-2} \text{mb}/(\text{MeV}/c)$ IIS, V. Mokeev, E. Isupov, A. Schmidt, Phys Rev D 112 , 114045 (2025)
ϕ	clas	$a = (0.34 \pm 0.12) \times 10^{-3} \mu\text{b}/(\text{MeV}/c)$ IIS, L. Pentchev, & A.I. Titov, Phys Rev C 101 , 045201 (2020)
J/ψ	GLUEX	$a = (0.43 \pm 0.12) \times 10^{-6} \mu\text{b}/(\text{MeV}/c)$ IIS, D. Epifanov, & L. Pentchev, Phys Rev C 101 , 042201 (2020)
Y	CENTER for NUCLEAR FEMTOGRAPHY	$a = (0.37 \pm 0.04) \times 10^{-9} \mu\text{b}/(\text{MeV}/c)$ IIS, W.J. Briscoe, L. Pentchev, & A. Schmidt, Phys Rev C 104 , 074028 (2021)

- Dramatic differences in hadronic factors $h^2 = a$, as slopes (a) of σ_t @ threshold as function of q varies significantly from ω to ϕ to J/ψ to Y .

- Therefore, such big difference in *SL* is determined mainly by *hadronic* factor h .





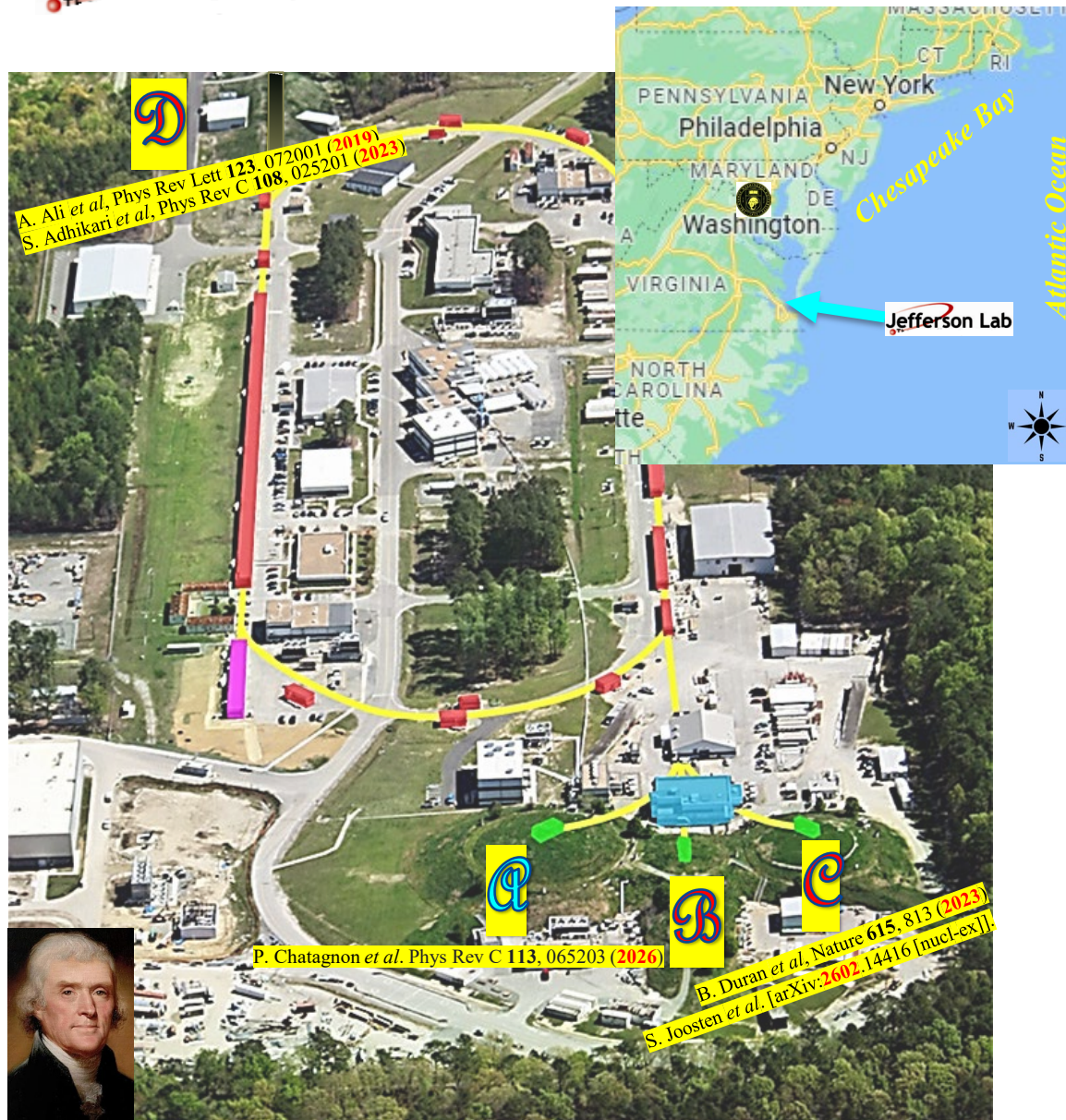
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*I Lab for Threshold I/ψ
Photoproduction on Proton*



Jefferson Lab Continuous Electron Beam Accelerator Facility in 2026



1995 — 2012...

Energy 0.4 — 6.0 GeV

- 200 μA , Polarization 85%
- Simultaneous delivery 3 Halls — A, B, C

- 500+ PhDs completed
- On average 22 US Ph.Ds per year, roughly 25–30% of US Ph.Ds in nuclear physics
- 1530 users in FY16, ~1/3 international from 37 countries

...2016 — ...

Energy 0.4 — 12.0 GeV

- 150 μA , Polarization 85%
- FY18: First simultaneous delivery to 4 Halls — A, B, C, D

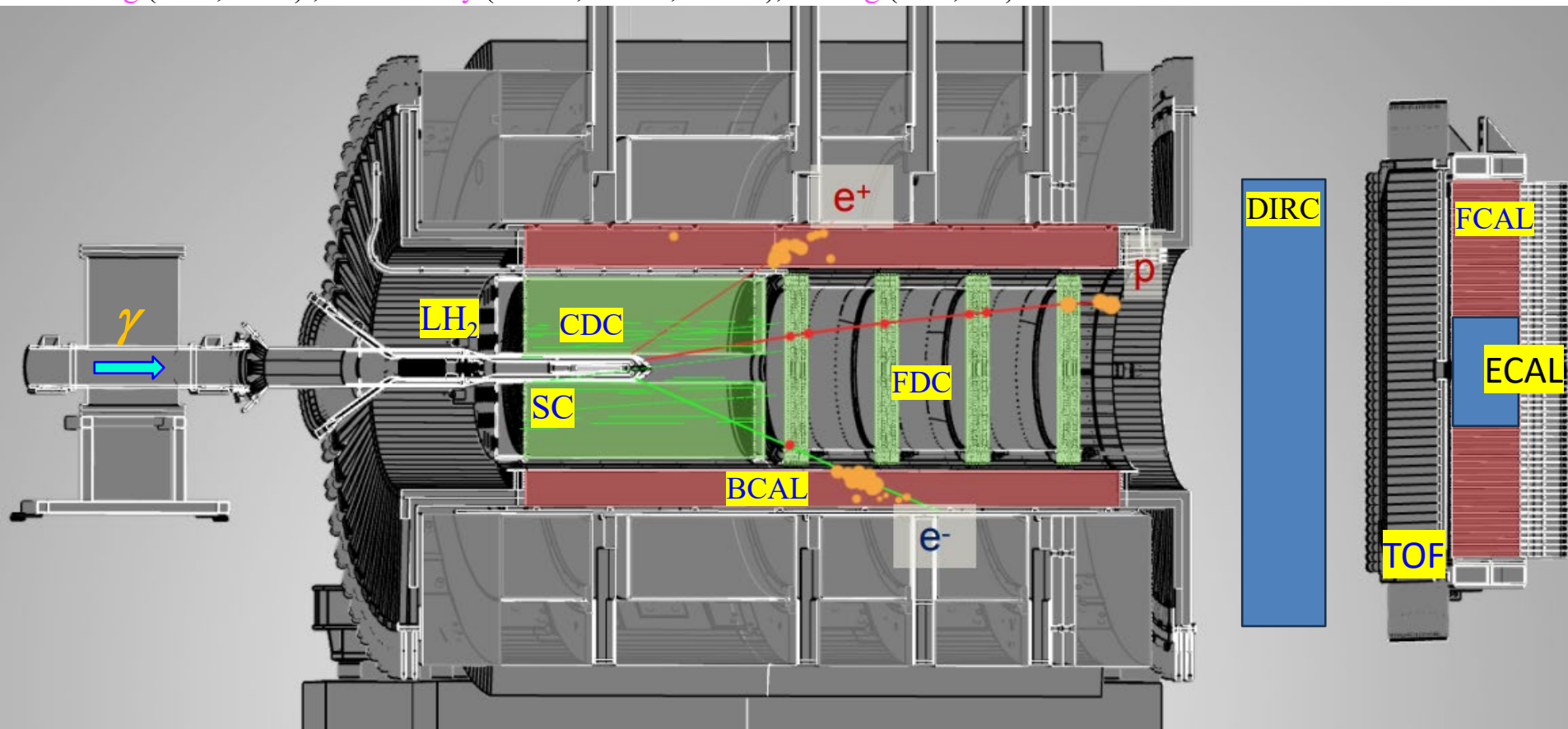
- Jefferson Lab with 12 GeV beam of e^- , has unique opportunity to measure high statistical J/ψ photoprod Xsec @ thr, which is 8.2 GeV.



Exclusive Reaction $\gamma p \rightarrow J/\psi p \rightarrow (e^+ e^-) p$ with **GLUEX** Detector

GLUEX detector has **full acceptance** - direct measurement of **total cross-section** - no need to extrapolate to low/high t

- 2T-solenoid, LH_2 target
- Tracking (FDC, CDC), Calorimetry (BCAL, FCAL, ECAL), Timing (TOF, SC)



- **Hermetic detector**: 10° – 120° *polar* & full *azimuthal* acceptance.
- **Tracking**: $\sigma_p/p \sim 1$ – 5% .
- **e^- separated from π^-** by E/p – energy deposition in calorimeters over measured momentum ($\pi^- > 10^3$ times more than e^-).
- **Intensity**: $(2$ – $5) \times 10^7$ γ /sec above J/ψ thr (8.2 GeV).
- **Calorimetry**: $\sigma_E/E \sim 6\% / \sqrt{E} + 2\%$.

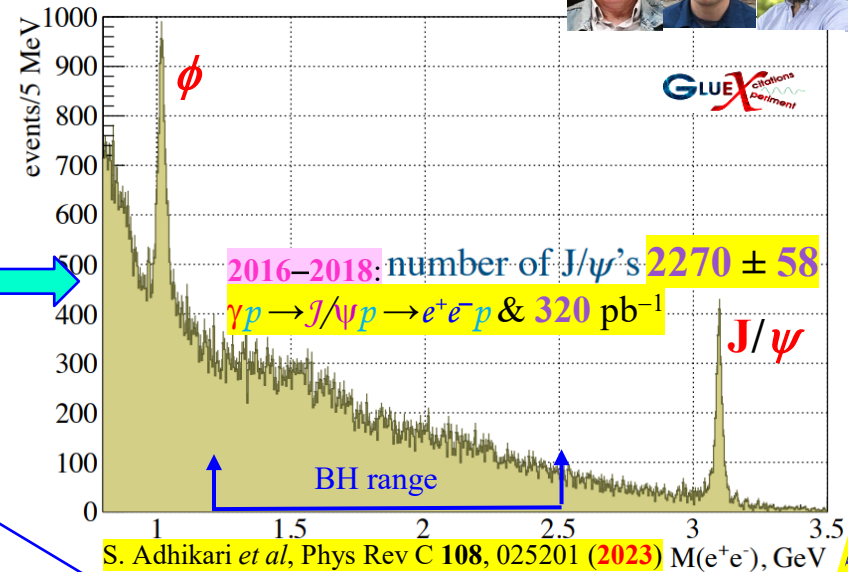
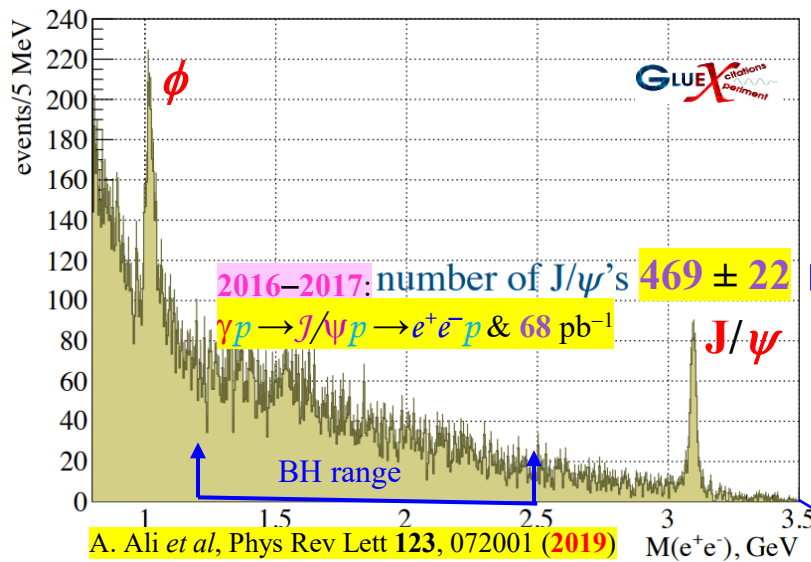
Courtesy of Lubomir Penchev, 2024



S. Adhikari *et al*, Nucl Inst Meth A **987**, 164807 (2021)



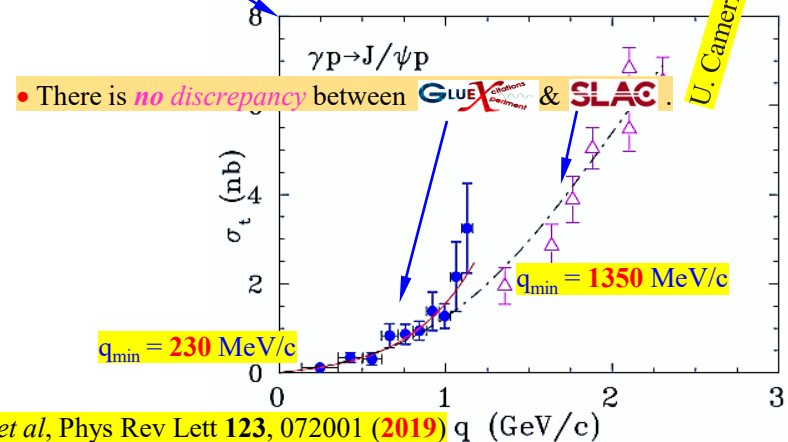
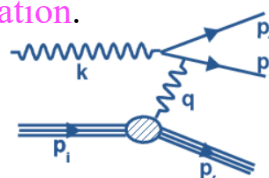
GLUEX citations experiment e^+e^- Invariant Mass Spectrum & Statistics



- Tagged photon beam (0.2% E_γ resolution) & exclusivity of reaction:
- Kinematic fit (constrained mostly by recoil proton): 13 MeV mass resolution; no radiative tail.
- J/ψ yields extracted from fits of $M(e^+e^-)$ distributions.
- BH (1.2 – 2.5 GeV) used for normalization.



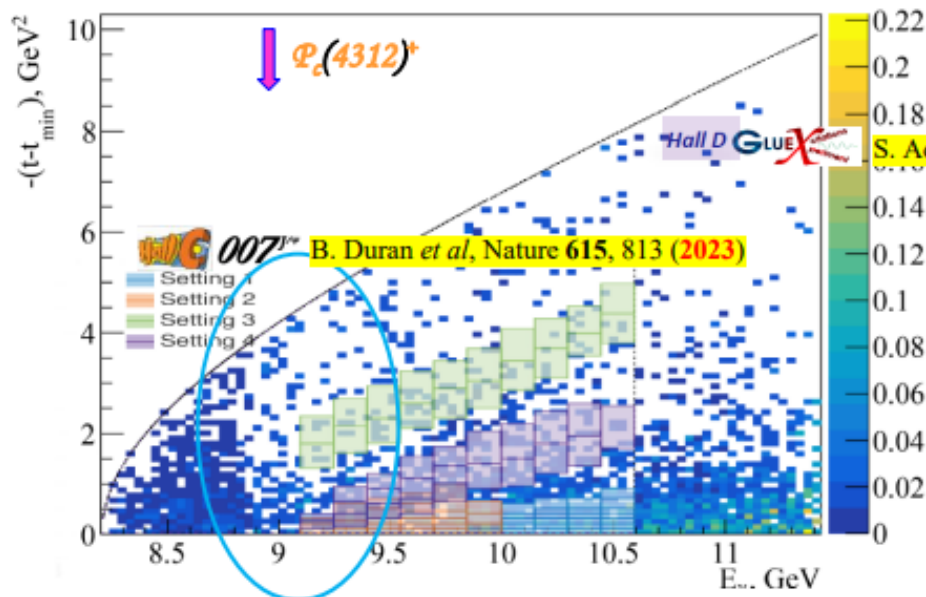
H. Bethe & W. Heitler, Proc Royal Soc London. Ser A, **146**, 83 (1934)



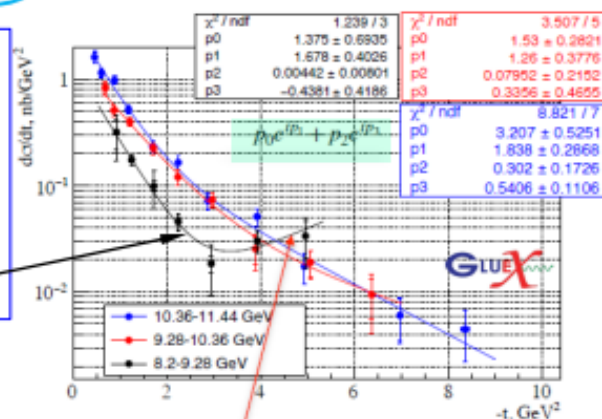
U. Camerini *et al*, Phys Rev Lett **35**, 483 (1975)



J/ψ Threshold Region Coverage



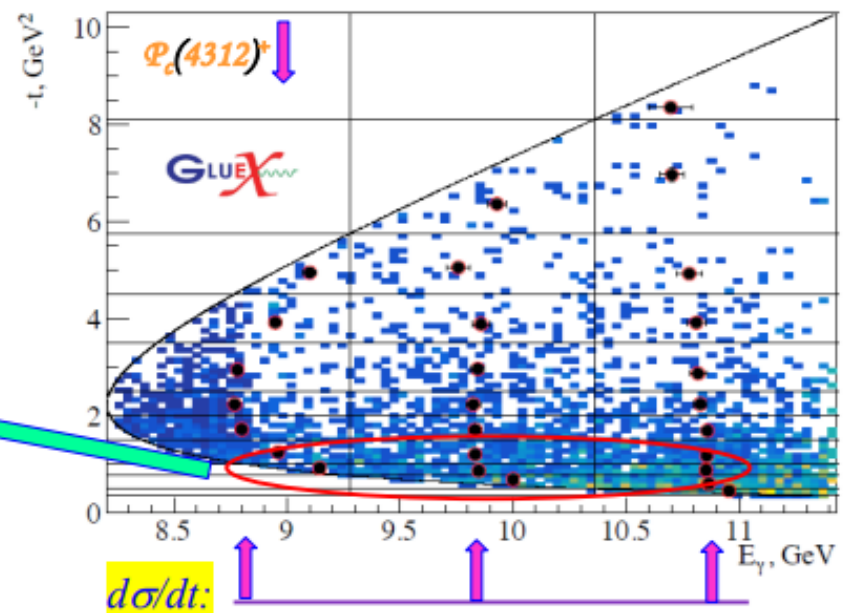
- Data is fitted with sum of two exponential functions.
- Second exponential contribution is most significant in lowest energy bin, where slope changes sign.



- Exponentially falling t -dependence

however:

- Enhancement of $d\sigma/dt$ at high t (for the lowest energy slice), indicates contribution beyond gluon exchange





$$\gamma p \rightarrow J/\psi p \rightarrow (e^+ e^-) p \rightarrow (\mu^+ \mu^-) p$$

B. Duran *et al*, Nature **615**, 813 (2023)

S. Joosten *et al*, arXiv:2602.14416 [nucl-ex]

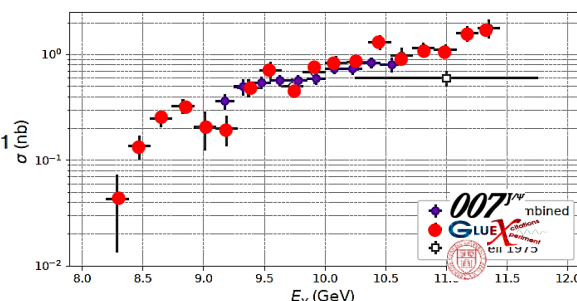
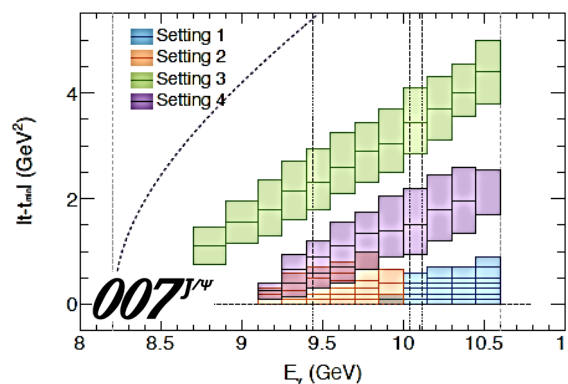
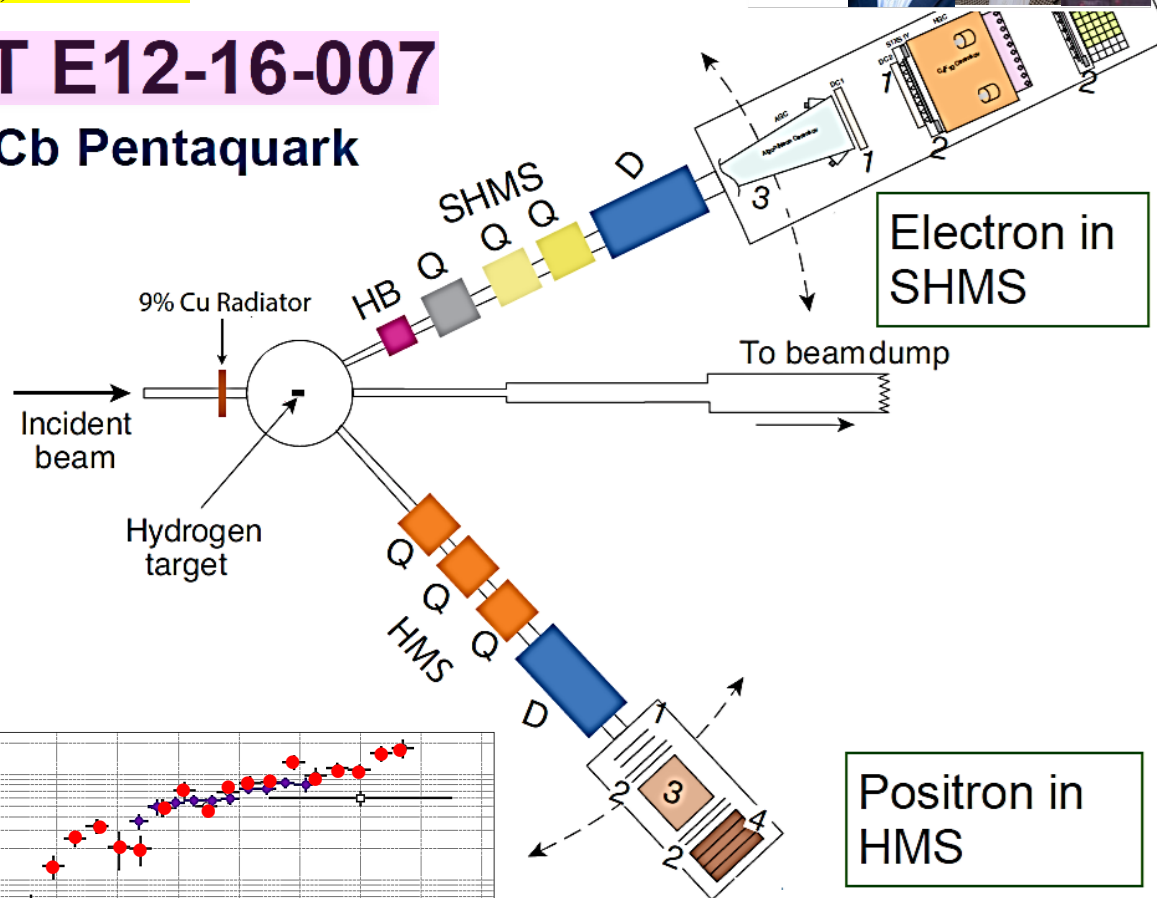


PDG: $\Gamma(e^+e^-) = \Gamma(\mu^+\mu^-) = 5.53 \text{ keV}$

JLAB EXPERIMENT E12-16-007

J/ψ-007: Search for the LHCb Pentaquark

- Ran February 2019 for ~8 PAC days
- High intensity real photon beam (50μA electron beam on a 9% copper radiator)
- 10cm liquid hydrogen target
- Detect J/ψ decay leptons in coincidence
 - Bremsstrahlung photon energy fully constrained



S. Ali *et al*, Inst Meth A **1083**, 171070 (2026)

Courtesy of Sylvester Joosten, July 2024



10/20/2026

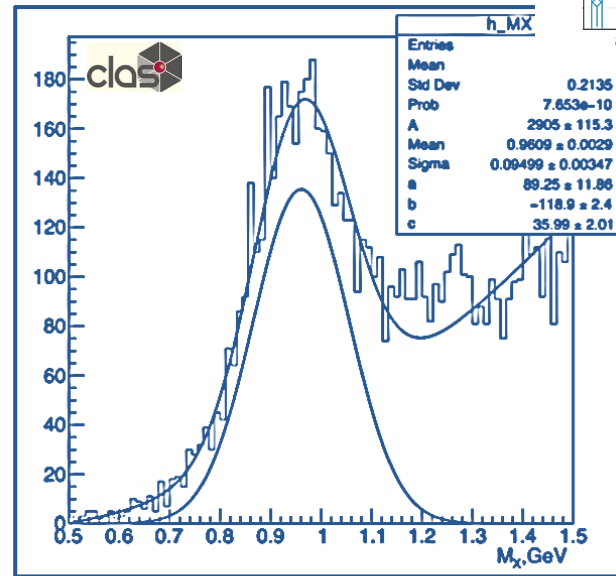
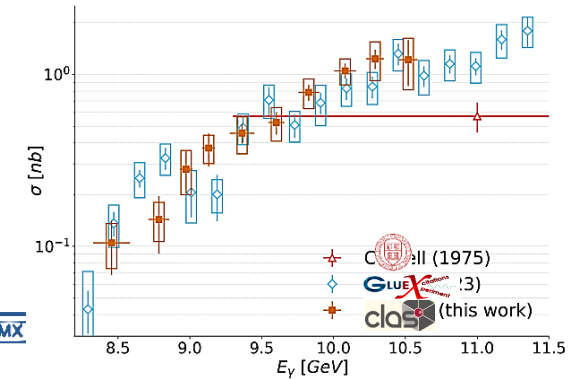
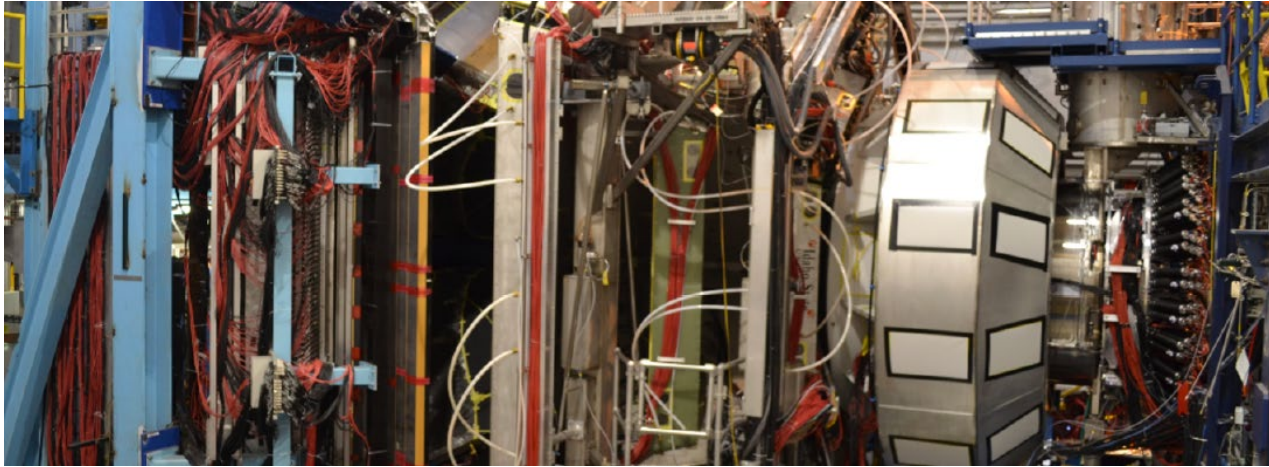
MENU 2026, Stony Brook U, NY, USA, October 2026

Igor Strakovsky 48



$\gamma^*p \rightarrow J/\psi p \rightarrow (e^+e^-)p$ Measurements from clas

P. Chatagnon *et al.* Phys Rev C **113**, 065203 (2026)



Missing mass distribution for the final state $e'e^+e^-$. The peak correspond to the missing mass of the proton.

V.D. Burkert *et al.*, Nucl Inst Meth A **959**, 163419 (2020).

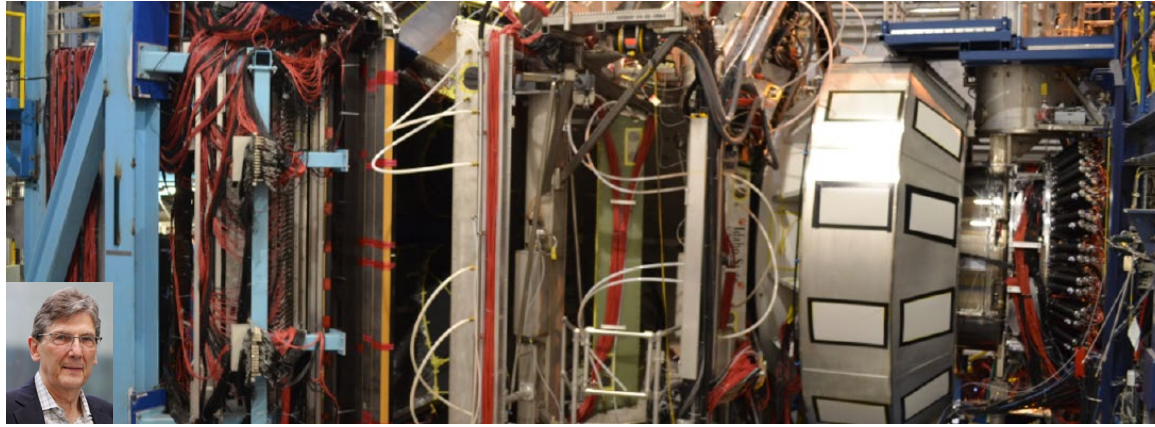
- For the reaction $ep \rightarrow e'e^+e^-(p')$
- The missing four-momentum is defined as $P_X = p_e + p_p - p_{e^-} - p_{e^+} - p_{e'}$
- The peak on the distribution should be around the mass of the missing proton.
- We keep events with $E_\gamma > 8.1$ GeV where $E_\gamma = E_{beam} - E_{e'}$
- Invariant mass $M^2(e^-e^+) = (p_{e^-} + p_{e^+})^2$ should be in the 2.0 GeV to 3.5 GeV region
- We also apply a cut in the missing mass as $|M_X - 0.9609| < 3\sigma$
- $Q^2 < 0.1$ GeV² ($Q^2 = 0 - 0.1$ GeV²)

Courtesy of Mariana Tenorio Pita, Nov. 2024

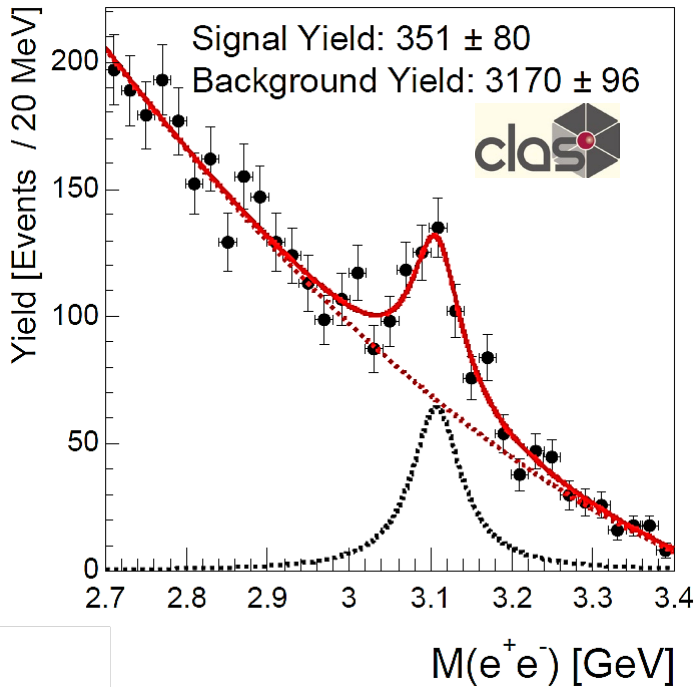


$\gamma^* "n" \rightarrow J/\psi p \rightarrow (e^+ e^-) p$ Measurements from clas

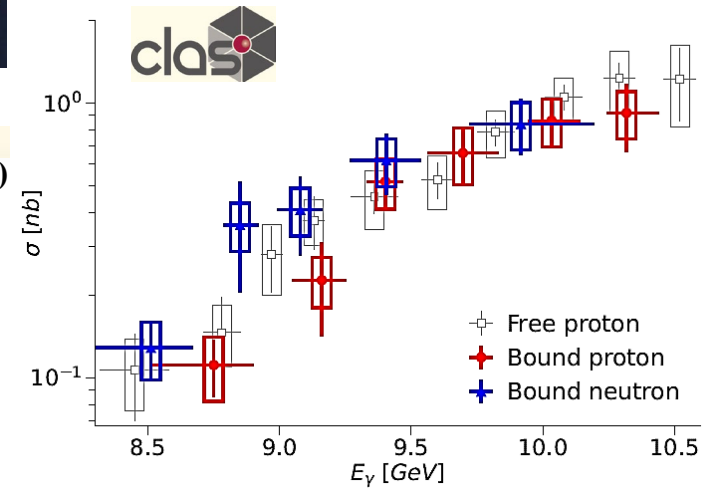
R. Tyson *et al.* arXiv:2609.03579 [nucl-ex]



V.D. Burkert *et al.*, Nucl Inst Meth A 959, 163419 (2020).



$Q^2 < 0.1 \text{ GeV}^2$ ($Q^2 = 0 - 0.1 \text{ GeV}^2$)





Discovery Park

Opportunities are emerging at Brookhaven National Laboratory.

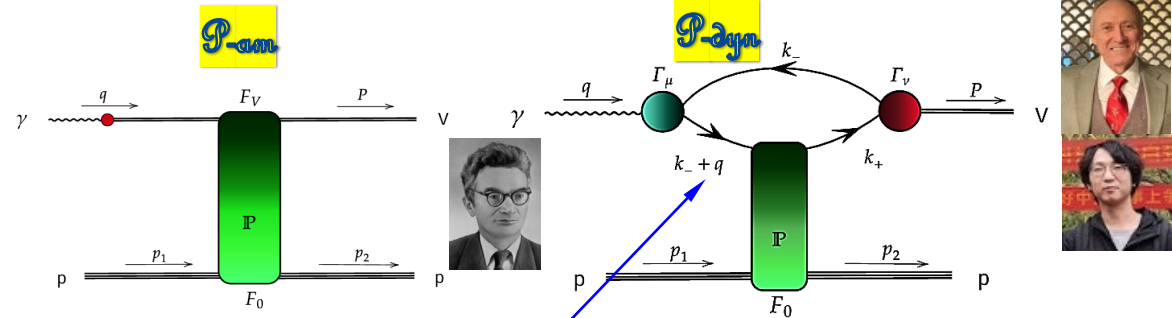
Nanjing & Bonn Universities
for $J/\psi - P$ SL





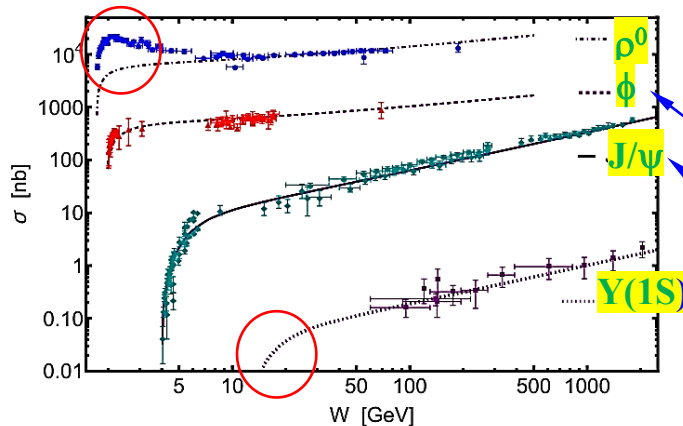
for $V\bar{M}$ Photoproduction

Lin Tang, Hui-Yu, Minghui Ding, & C.D. Roberts, Eur Phys J C **86**, 264 (2026)



- Good description of data is mainly provided by explicit implementation of *upper quark loop*.
- Of course, there is NO reason for *Pomeron* dominance near thr.
- There is **no fit** to diff. & total Xsec & predictions are really good.

Pomeron is *pole* in complex moment j -plane, but *not pole* in M^2 plane. Moreover, *BFKL Pomeron* is not even *pole* in j -plane. It is *cut* in j -plane. Usually, one said that *Pomeron* is rightmost *singularity* in j -plane.



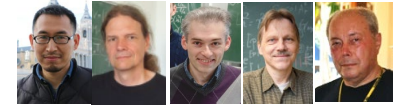
Meson	Photoproduction SL (fm)	dynSL (fm)
ϕ	0.063 ± 0.010 [14]	0.123
J/ψ	$0.00274 \pm 0.00027^\dagger$	0.00634
Υ	0.00051 ± 0.00003 [17]	0.00196

Experiment

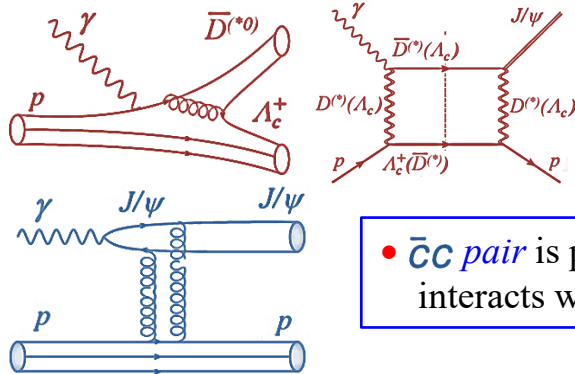


Deciphering Mechanism of Near-Threshold J/ψ Photoproduction

Meng-Lin Du, V. Baru, Feng-Kun Guo, Ch. Hanhart, U.-G. Meissner, A. Nefediev, & IIS, Eur Phys J C **80**, 1053 (2020)



- It was shown that fluctuation of *photon* into *open charm* $\gamma p \rightarrow \Lambda_c \bar{D}$ is preferable than into *hidden charm* J/ψ . K. Boreskov, A. Capella, A. Kaidalov, & J. Tran Thanh Van, Phys Rev D **47**, 919 (1993)



- $\bar{c}c$ pair is produced by *1g* & interacts with *proton*.

- $\bar{c}c$ pair is produced by *photon* via *VMD* & interacts with *proton* through *2g* exchange.

- Coupled-channel mechanism with *VMD*

$$\begin{aligned} |a^{J=1/2}| &= 0.2 \dots 3.1 \text{ mfm} \\ |a^{J=3/2}| &= 0.2 \dots 3.0 \text{ mfm} \end{aligned}$$

- These *two mechanisms* act simultaneously. Assuming there is only *first* one, then key consequence: *threshold cusps* !
- There is no fit to *GLUEX* data.

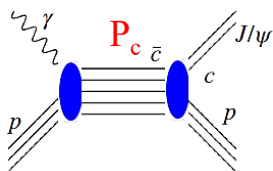
- One *should study* two-component problem accounting for *interference* between these *two components*.
- Effect of *charm* exchange is smaller than *gluon* exchange.
- Gluon* contribution can be strongly *suppressed* due to “*young*” effect.



E.L. Feinberg, Sov Phys Usp, **23**, 629 (1980)

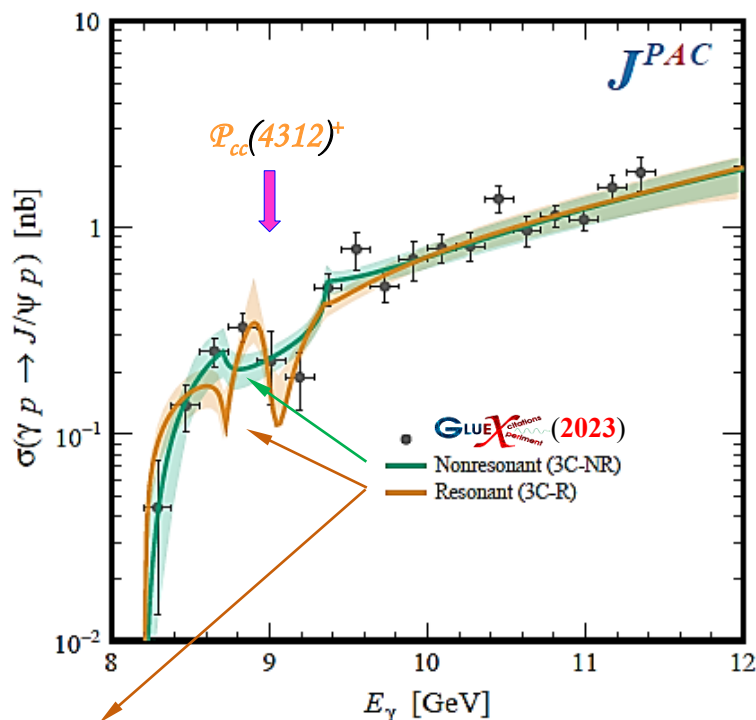
Courtesy of Misha Ryskin, July 2020





J^{PAC} for J/ψ Photoproduction

D. Winney *et al*, Phys Rev C **108**, 054018 (2023)



$|a_{\psi p}| \lesssim 0.2 \text{ fm}$ at a 90% CL

➡ Much-much larger than we found.

Pole position
(no uncertainties)

$M_R = 4211 \text{ MeV}$
 $\Gamma_R = 48 \text{ MeV}$

➡ 101 MeV below $\sqrt{s_{th}}$
24 MeV below us

Phenomenological model based on
s-channel PW expansion ($l < 3$):

- Global fit of both $\sqrt{s}$ & $D \, d\sigma/dt(t)$ & Hall $D \, \sigma_{tot}(E_\gamma)$
 - (1C) $J/\psi p$ interaction
 - (2C) $J/\psi p$ interaction & $\bar{D}^* \Lambda_c$
 - (3C-NR) $J/\psi p$, $\bar{D} \Lambda_c$, $\bar{D}^* \Lambda_c$ (non-res soln)
 - (3C-NR) $J/\psi p$, $\bar{D} \Lambda_c$, $\bar{D}^* \Lambda_c$ (res soln)

• **No stat significant preference:**

- $E_\gamma = 9 \text{ GeV}$ structure requires sizable contribution from *open charm*.
- Severe violation of **VMD** & factorization *not excluded*.
- s-channel resonance *not excluded*.
- t-enhancement maybe due to *proximity* to threshold (s-wave only).

• Precise measurements critically important to disentangle *reaction mechanism @ threshold*.



Narrow Pentaquarks from $\Lambda_b^0 \rightarrow P_{c\bar{c}}^+ K^- \rightarrow (J/\psi p) K^-$

Bump Hunting

“Not every *bump* is a *resonance*,
not every *resonance* is a *bump*”
R. Gordon Moorhouse (1960s)



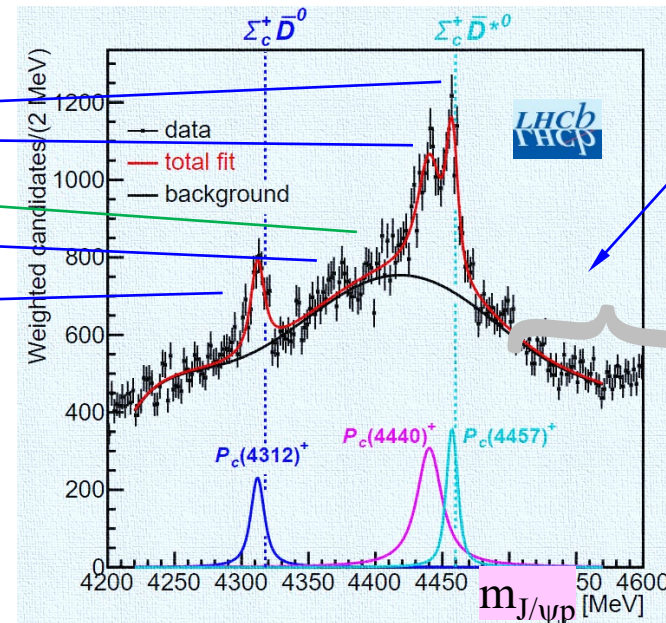
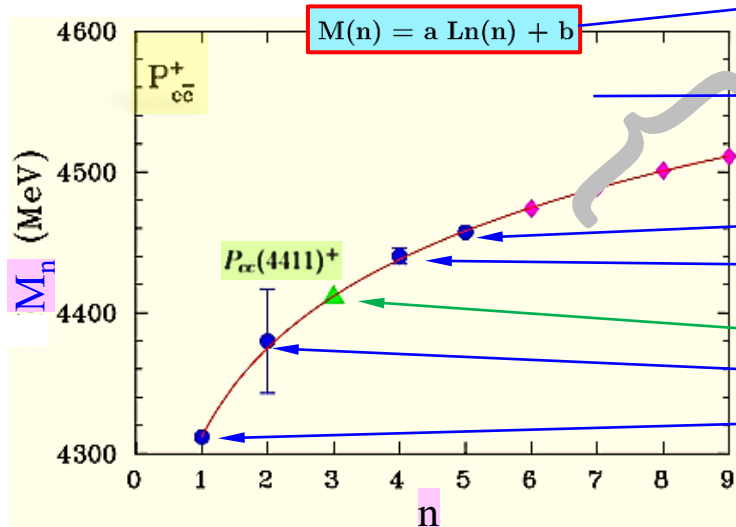
$$I(J^P) = \frac{1}{2}(??)$$

State PDG	Mass (MeV)	$\Gamma[P_{cc} \rightarrow J/\psi p]$ (MeV)	Significance (σ)
$P_{cc}(4312)^+$	$4311.9 \pm 0.7^{+6.8}_{-0.6}$	$9.8 \pm 2.7^{+3.7}_{-4.5}$	7.3
$P_{cc}(4380)^+$	$4380 \pm 8 \pm 29$	$205 \pm 18 \pm 86$	...
$P_{cc}(4440)^+$	$4440.3 \pm 1.3^{+4.1}_{-4.7}$	$20.6 \pm 4.9^{+8.7}_{-10.1}$	5.4
$P_{cc}(4457)^+$	$4457.3 \pm 0.6^{+4.1}_{-1.7}$	$6.4 \pm 2.0^{+5.7}_{-1.9}$	5.4



R. Aaij *et al*, Phys Rev Lett **122**, 222001 (2019)

R. Aaij *et al*, Phys Rev Lett **115**, 072001 (2015)



L. David Roper & IIS, Eur. Phys. J. A **61**, 102 (2025).



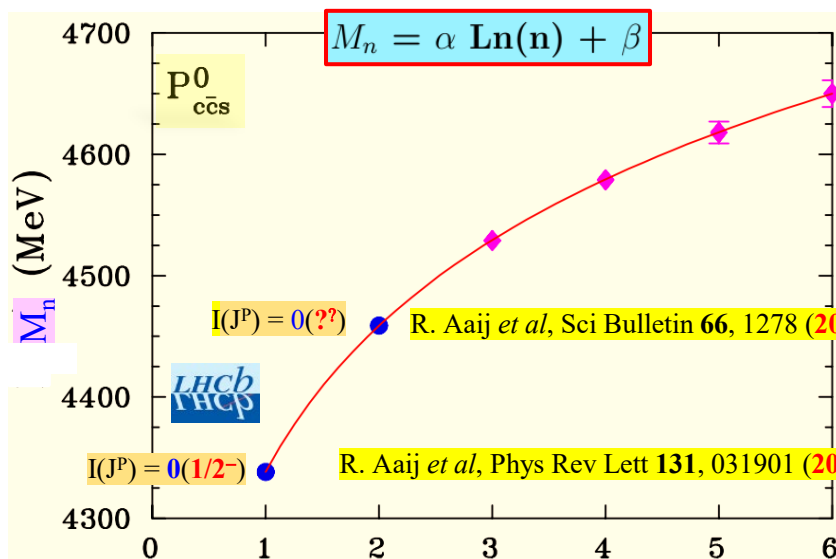
Narrow Pentaquarks from $\Xi_b^- \rightarrow P_{ccs}^0 K^- \rightarrow (J/\psi \Lambda) K^-$ & $B^- \rightarrow P_{ccs}^0 \bar{p} \rightarrow (J/\psi \Lambda) \bar{p}$

- First evidence of a structure in the $J/\psi \Lambda$ invariant mass distribution is obtained from an amplitude analysis of $\Xi_b^- \rightarrow J/\psi \Lambda K^-$ decays. The observed structure is consistent with being due to a charmonium pentaquark with strangeness with a significance of 3.1σ including systematic uncertainties and look-elsewhere effect. Its mass and width are determined to be $4458.8 \pm 2.9^{+4.7}_{-1.1}$ MeV and $17.3 \pm 6.5^{+8.0}_{-5.7}$ MeV, respectively, where the quoted uncertainties are statistical and systematic. The structure is also consistent with being due to two resonances. In addition, the narrow excited Ξ^- states, $\Xi(1690)^-$ and $\Xi(1820)^-$, are seen for the first time in a Ξ_b^- decay, and their masses and widths are measured with improved precision. The analysis is performed using pp collision data corresponding to a total integrated luminosity of 9 fb^{-1} , collected with the LHCb experiment at centre-of-mass energies of 7, 8 and 13 TeV.

R. Aaij *et al*, Sci Bulletin 66, 1278 (2021)

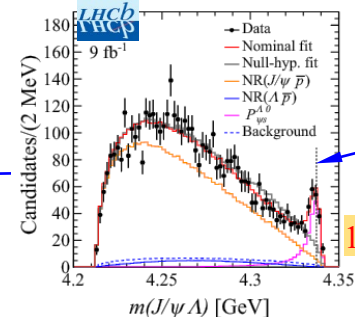
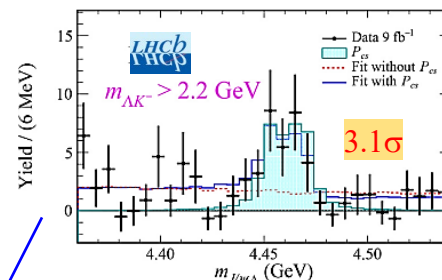
- An amplitude analysis of $B^- \rightarrow J/\psi \Lambda \bar{p}$ decays is performed using 4400 signal candidates selected on a data sample of pp collisions recorded at center-of-mass energies of 7, 8, and 13 TeV with the LHCb detector, corresponding to an integrated luminosity of 9 fb^{-1} . A narrow resonance in the $J/\psi \Lambda$ system, consistent with a pentaquark candidate with strangeness, is observed with high significance. The mass and the width of this new state are measured to be $4338.2 \pm 0.7 \pm 0.4$ MeV and $7.0 \pm 1.2 \pm 1.3$ MeV, where the first uncertainty is statistical and the second systematic. The spin is determined to be $1/2$ and negative parity is preferred. Because of the small Q -value of the reaction, the most precise single measurement of the B^- mass to date, $5279.44 \pm 0.05 \pm 0.07$ MeV, is obtained.

R. Aaij *et al*, Phys Rev Lett 131, 031901 (2023)



R. Aaij *et al*, Sci Bulletin 66, 1278 (2021)

R. Aaij *et al*, Phys Rev Lett 131, 031901 (2023)



L. David Roper & IIS, Eur. Phys. J. A 61, 225 (2025).

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