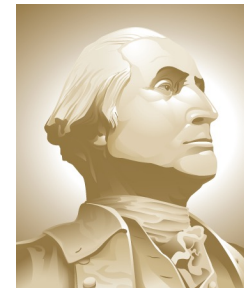


Searching for the LHCb $P_c(4312)^+$ at Jefferson Lab and J-PARC

Axel Schmidt

NSTAR 2024, York, United Kingdom

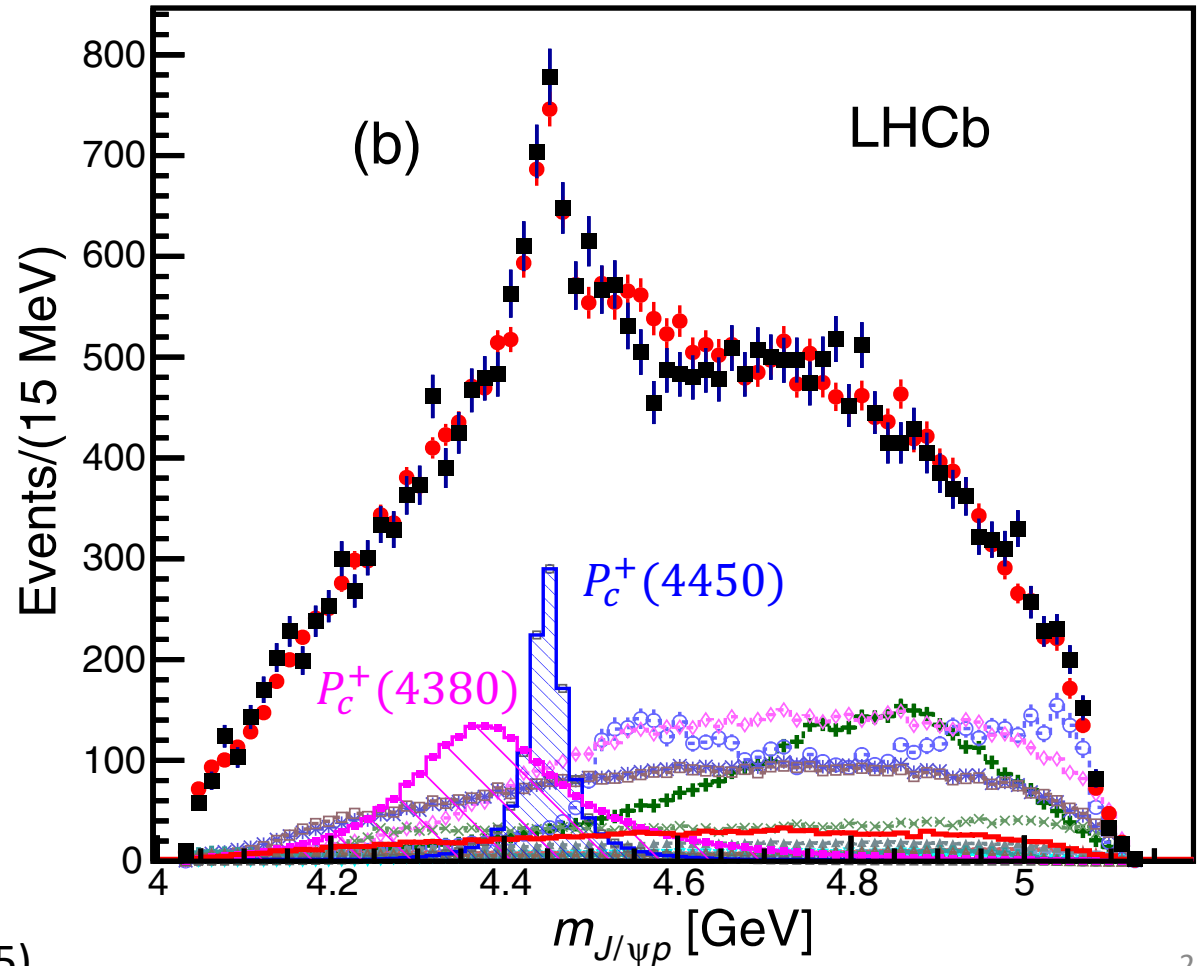
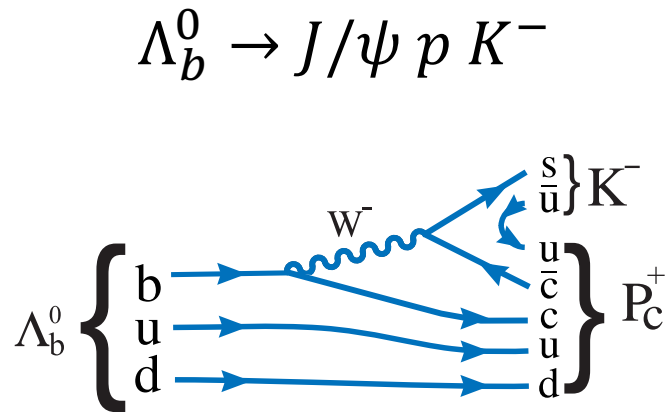
June 20, 2024



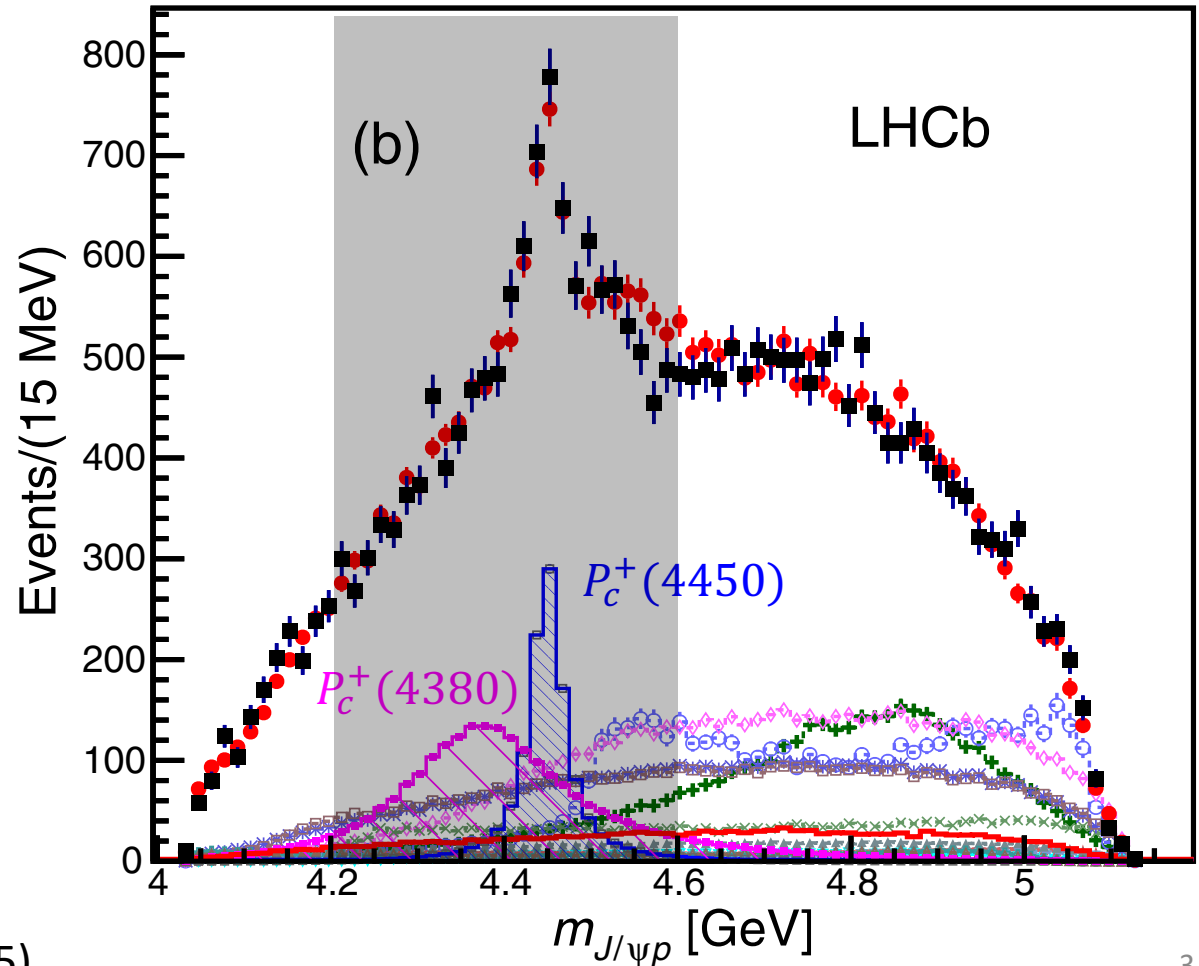
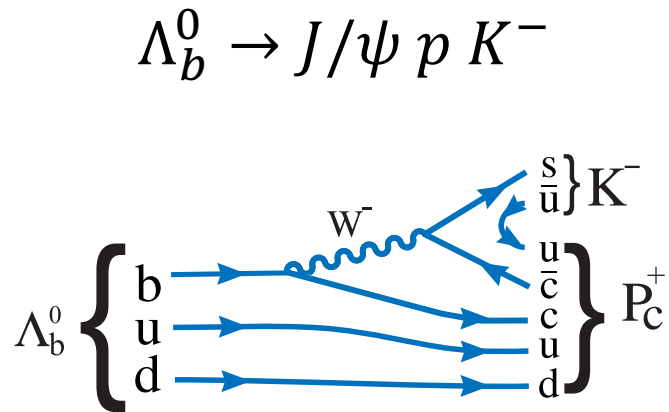
THE GEORGE
WASHINGTON
UNIVERSITY

WASHINGTON, DC

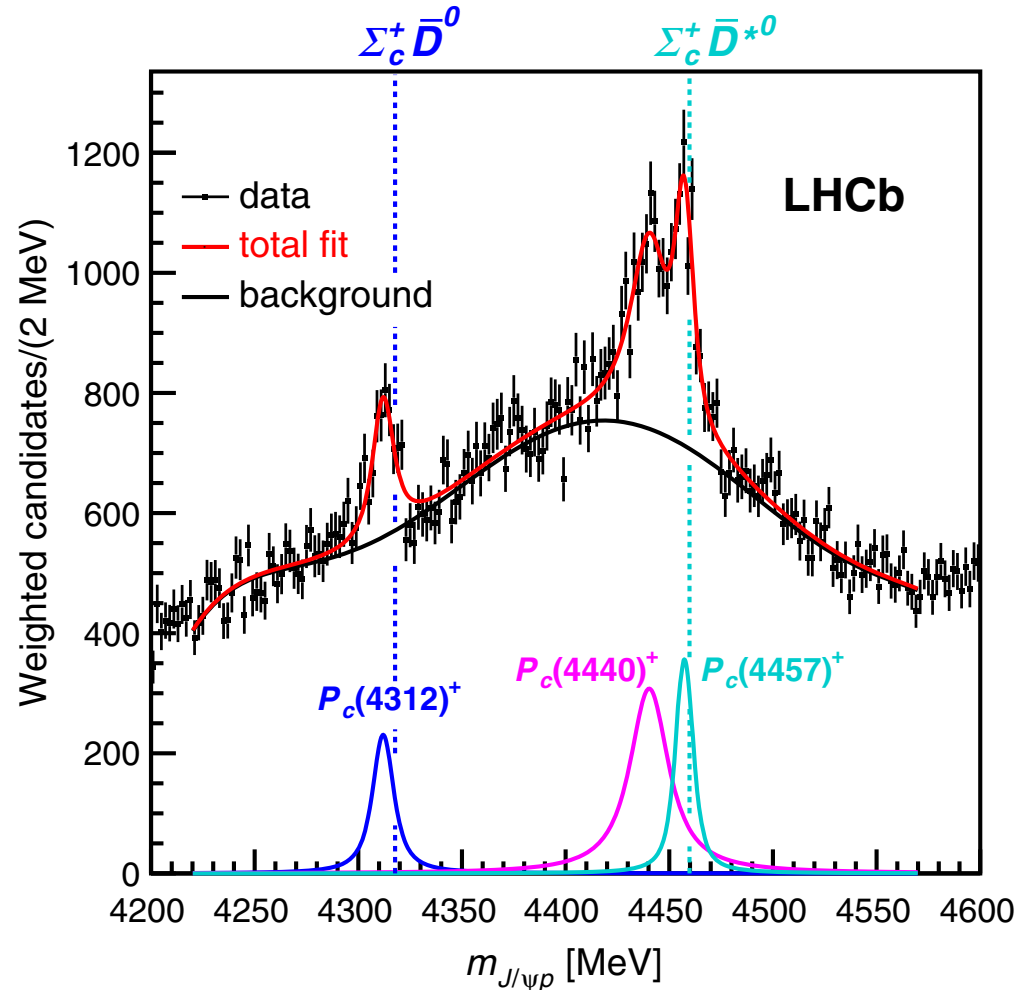
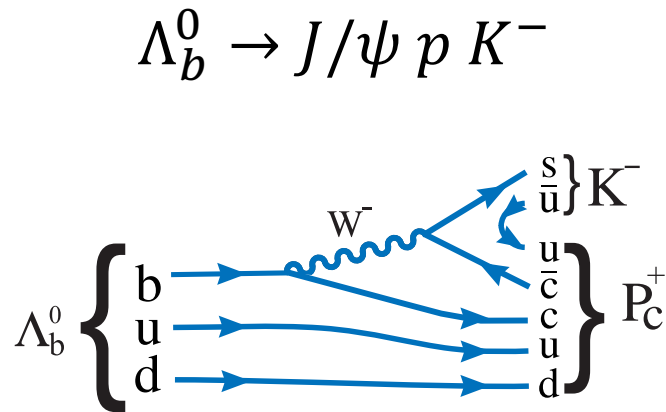
LHCb pentaquark candidates seen in $J/\psi p$



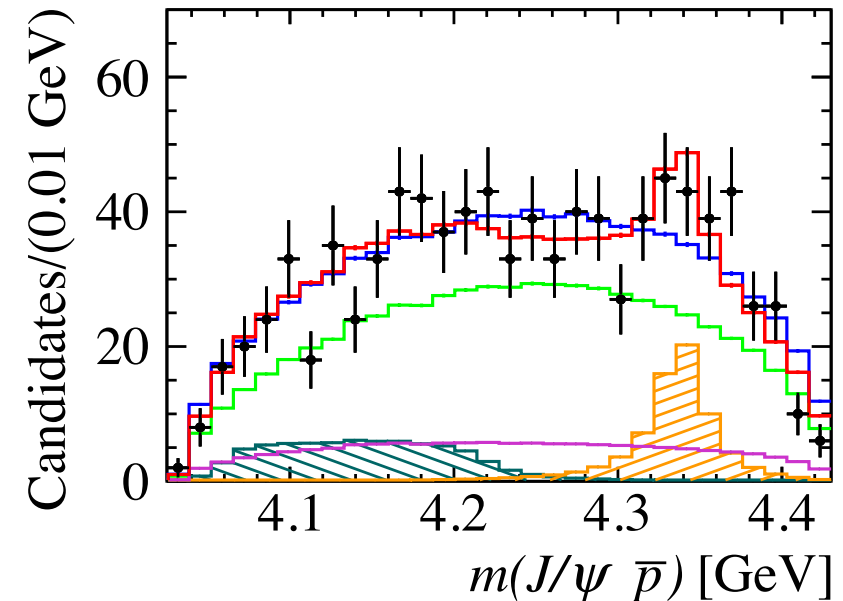
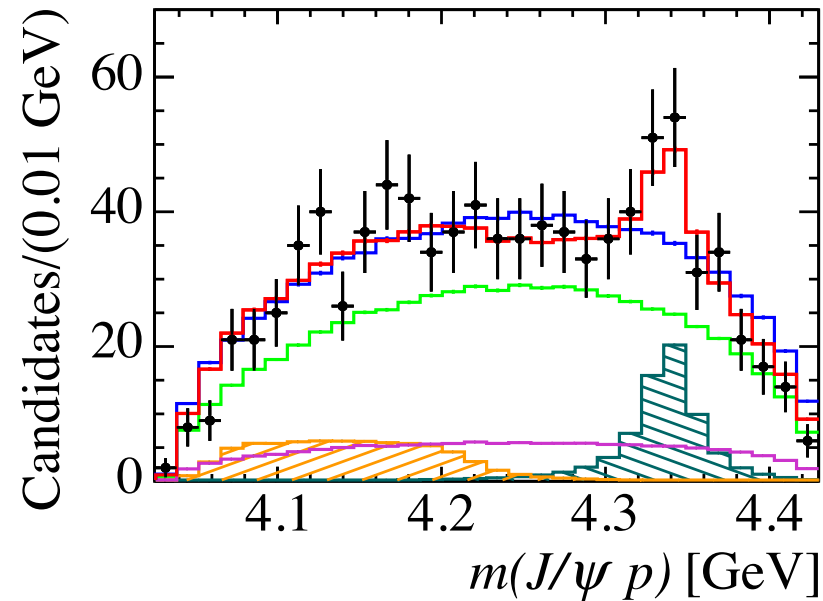
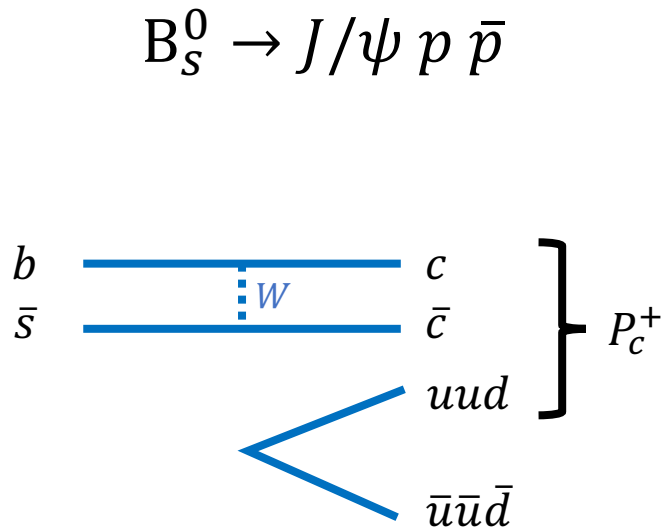
LHCb pentaquark candidates seen in $J/\psi p$



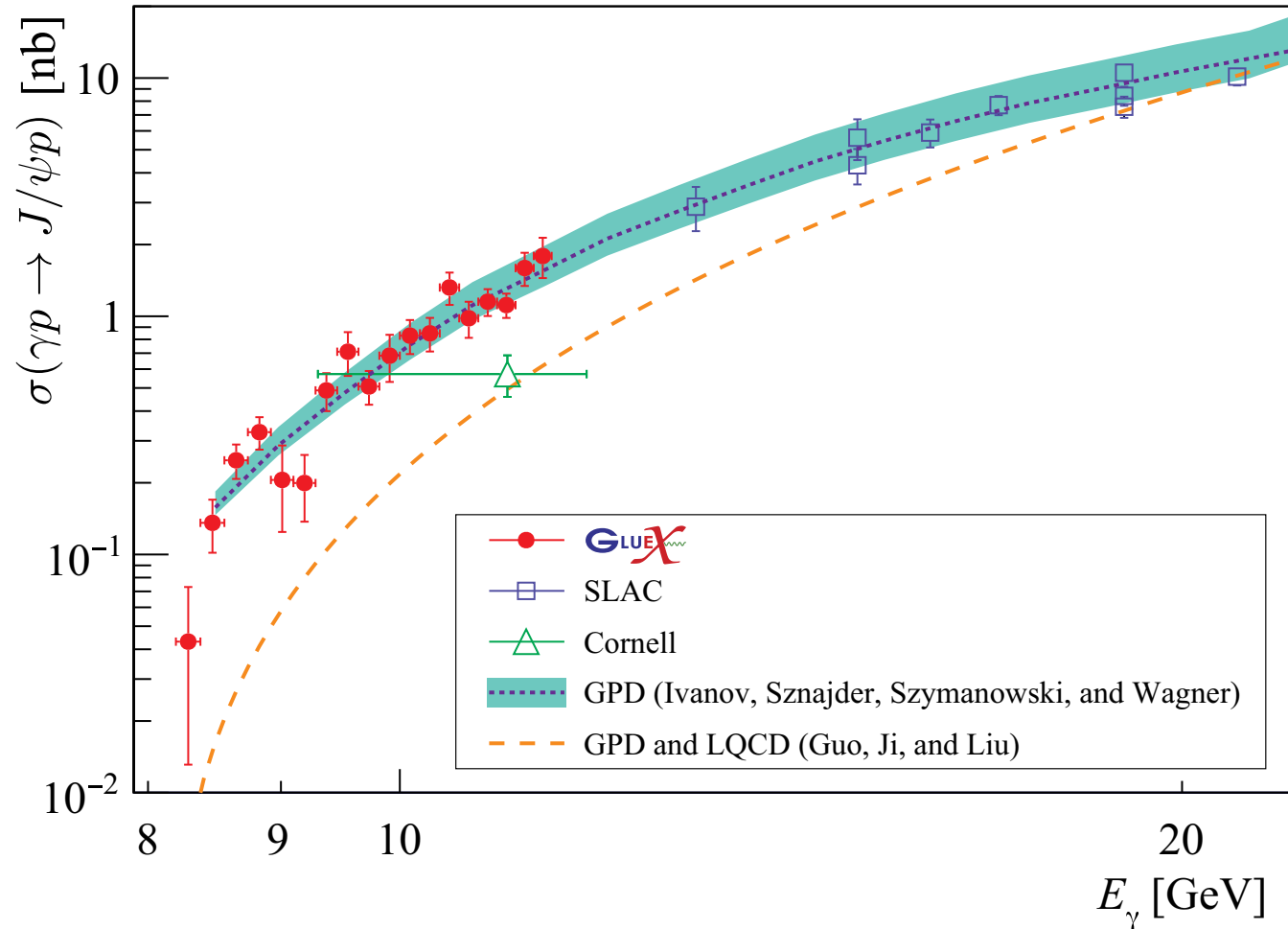
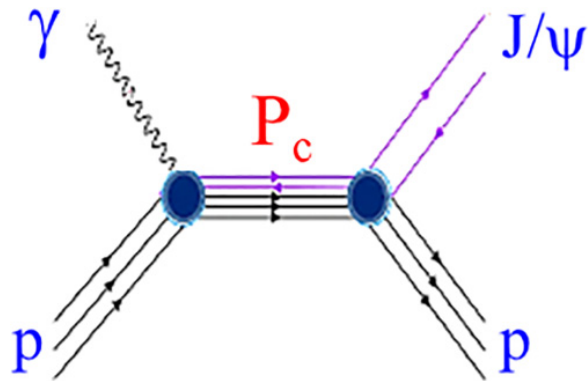
LHCb pentaquark candidates seen in $J/\psi p$



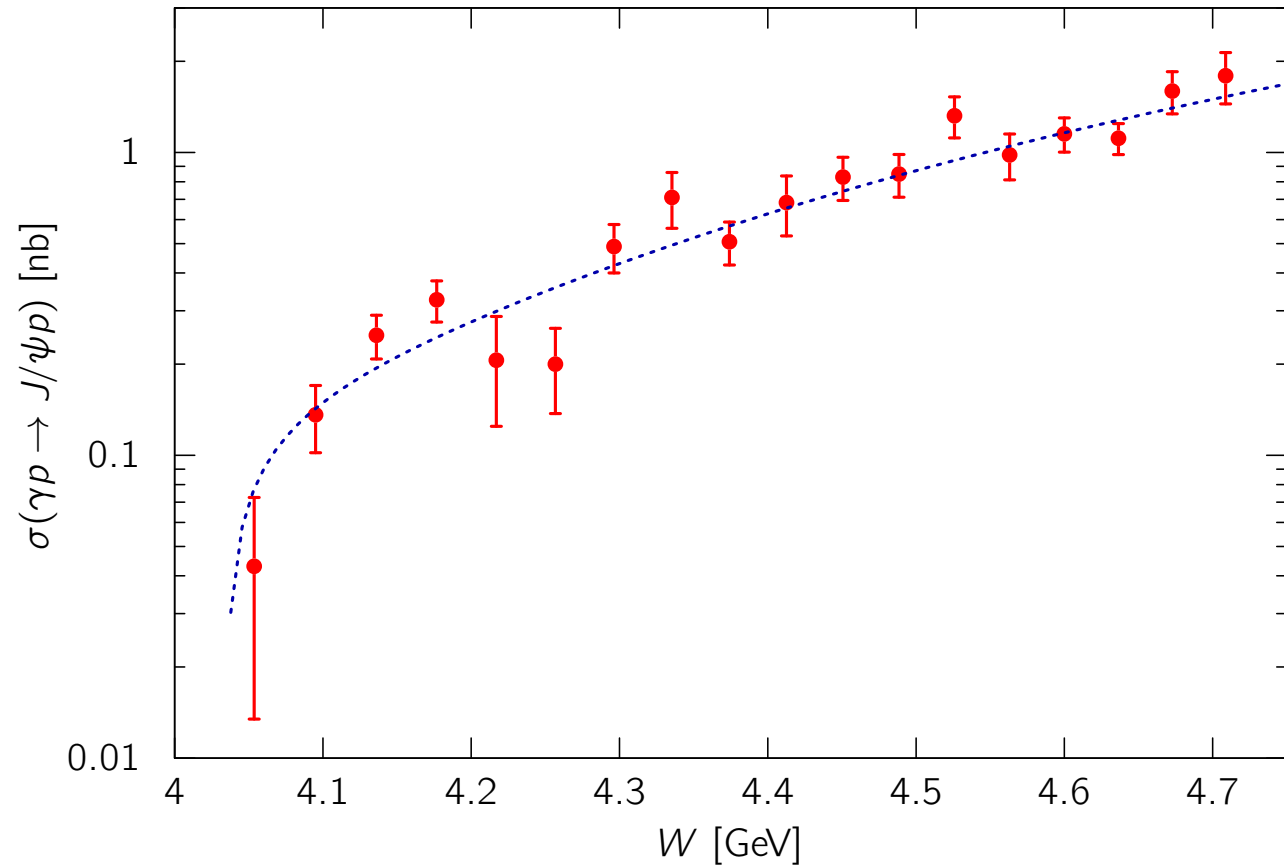
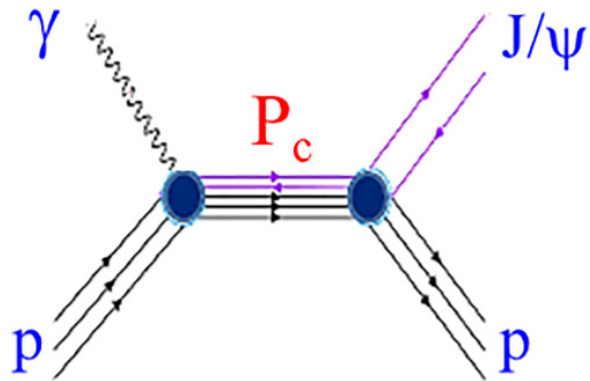
LHCb pentaquark candidates seen in $J/\psi p$



Search for a $J/\psi p$ resonance at GlueX



Search for a J/ψ p resonance at GlueX



Possible interpretation: destructive interference between resonance and background

Plausibility of the LHCb $P_c(4312)^+$ in the GlueX $\gamma p \rightarrow J/\psi p$ total cross sections

[Phys. Rev. C 108, 015202 \(2023\)](#), [arXiv:2304.04924 \[hep-ph\]](#)

Igor Strakovsky

William Briscoe

Eugene Chudakov

Ilya Larin

Lubomir Pentchev

Axel Schmidt

Ron Workman



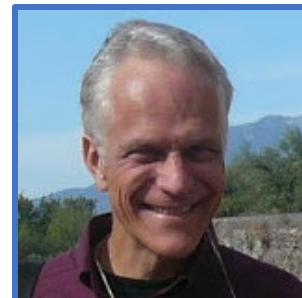
Strakovsky



Briscoe



Workman



Chudakov



Larin

Simple model assuming dominant s-wave

Assume:

$$\sigma = \frac{\pi}{4k^2} \left| \overset{\text{background}}{b} + \overset{\text{resonance}}{R} e^{2i\alpha} \right|$$

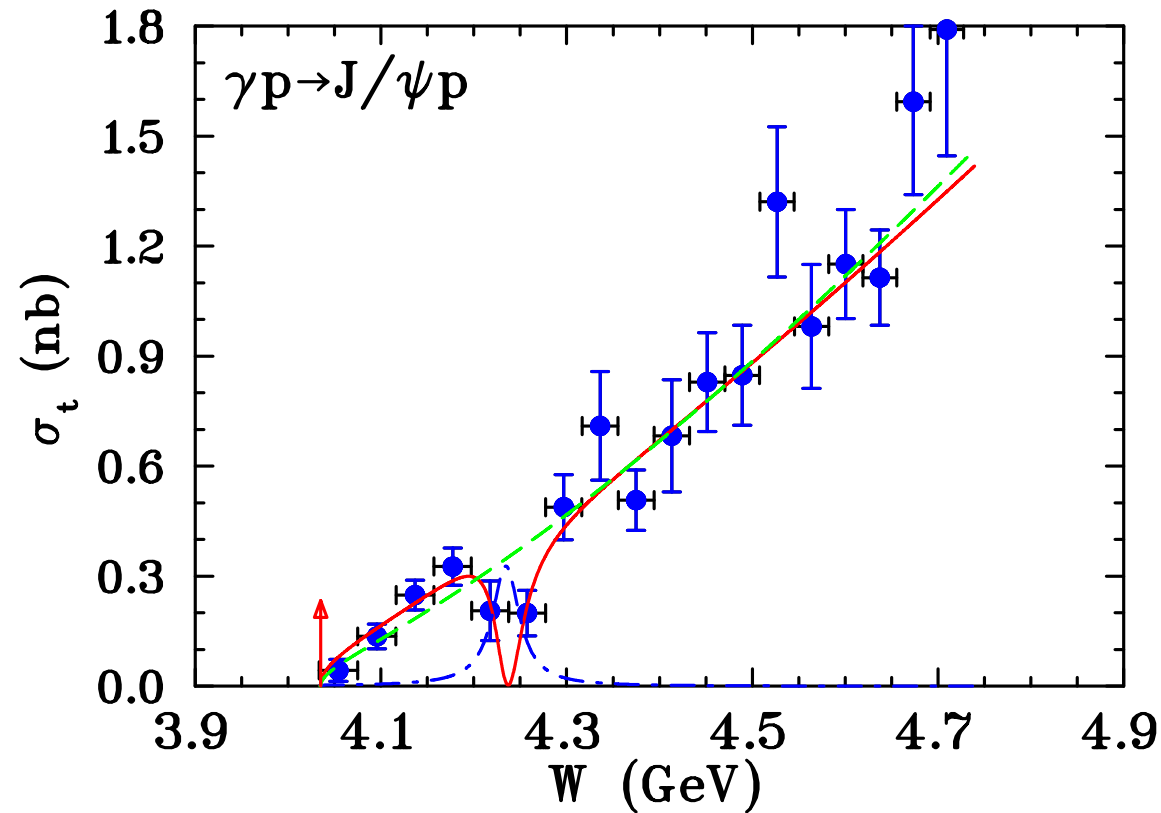
Background:

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

Resonance:

$$R = \frac{2\Gamma M}{M^2 - s - i\Gamma M} X$$

Best fit prefers destructive interference



Best Fit Results

$$\chi^2/dof = 11.99/12 = 1.00$$

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

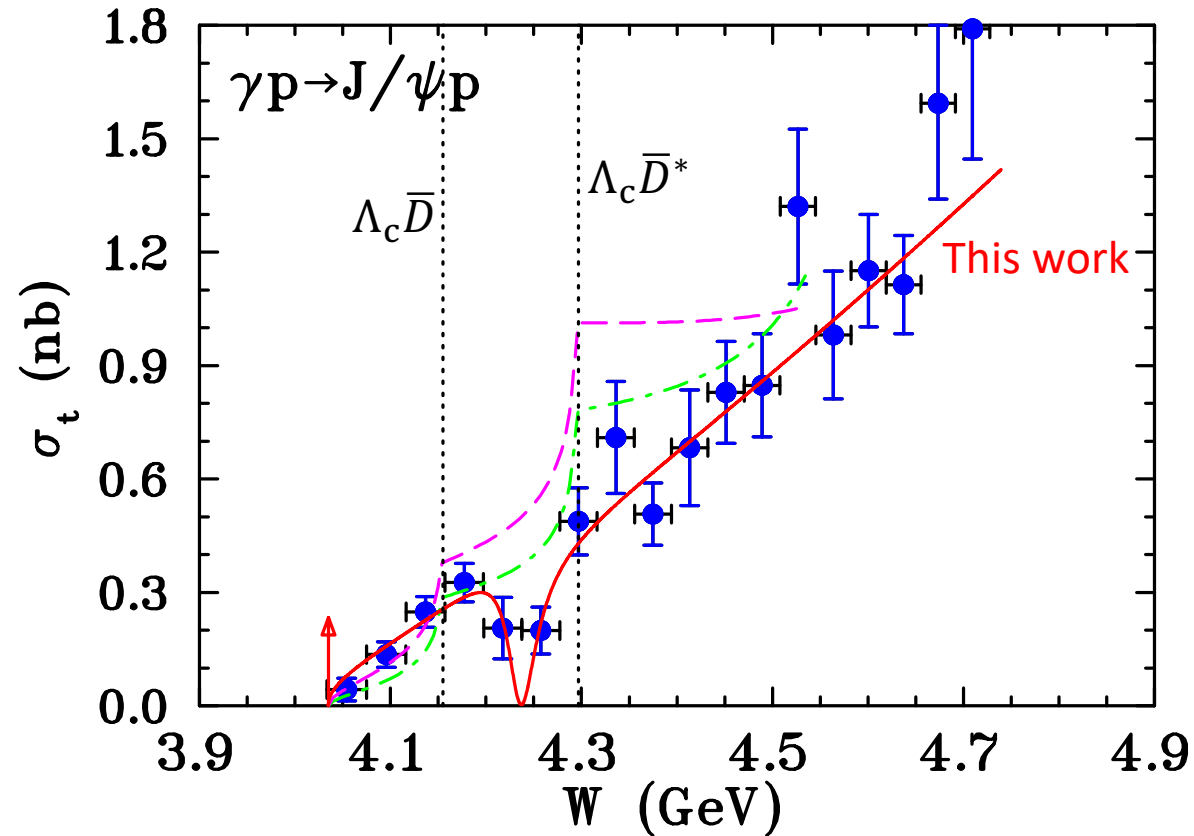
$$\Gamma = 35.4 \pm 8.2 \text{ MeV}$$

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

Background only

$$\chi^2/dof = 19.74/16 = 1.23$$

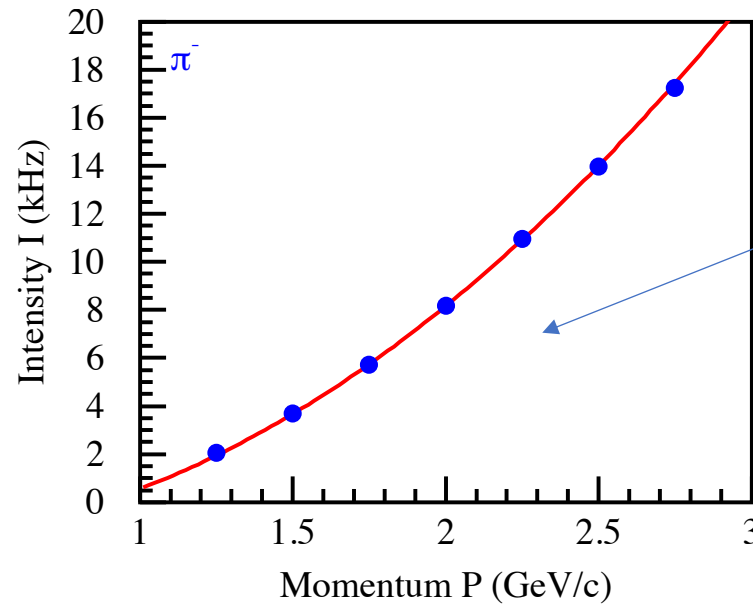
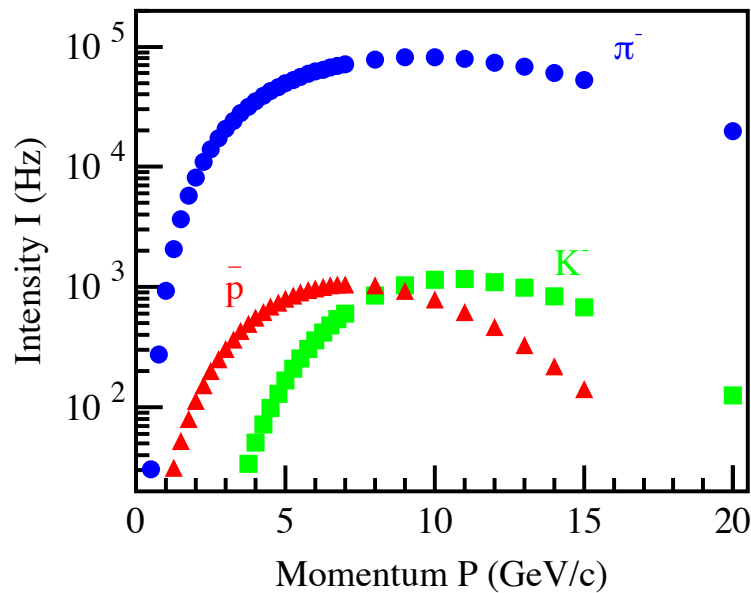
Open charm models also predict cusp-like behavior.



- Du, Baru, Guo, Hanhart, Meißner, Nefediev, I. Strakovsky
- Eur. Phys. J. C 80, 1053 (2020).

π^- Scattering at J-PARC

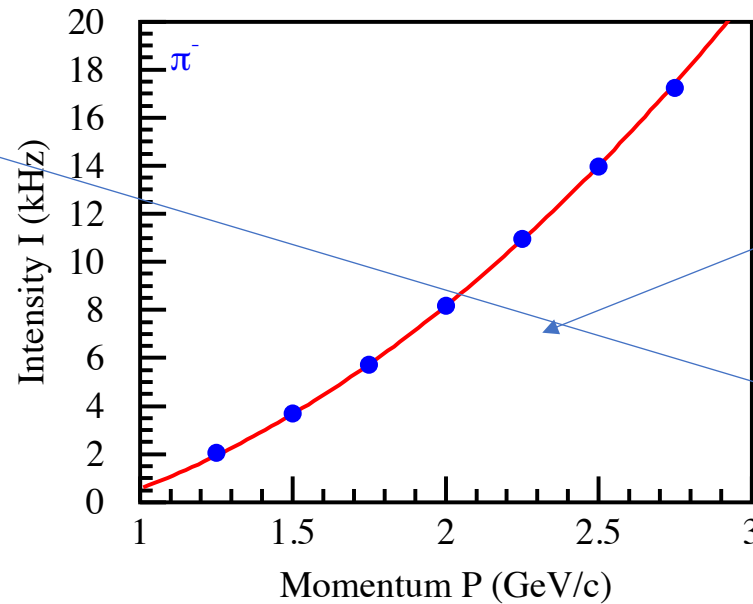
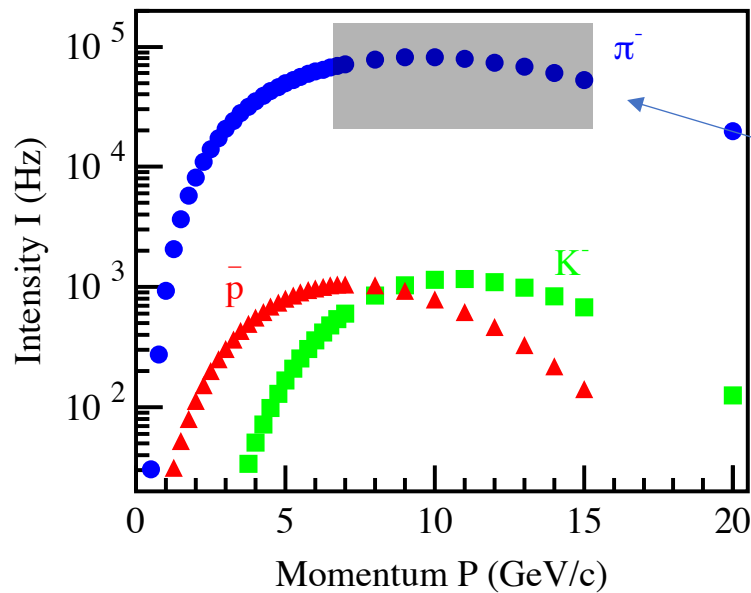
- High-momentum beamline: 30 GeV primary protons
- P95 Proposal
 - Production target for secondary beams.



Energy range relevant for
 $\pi^- p \rightarrow \phi n$

π^- Scattering at J-PARC

- High-momentum beamline: 30 GeV primary protons
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 - Production target for secondary beams.



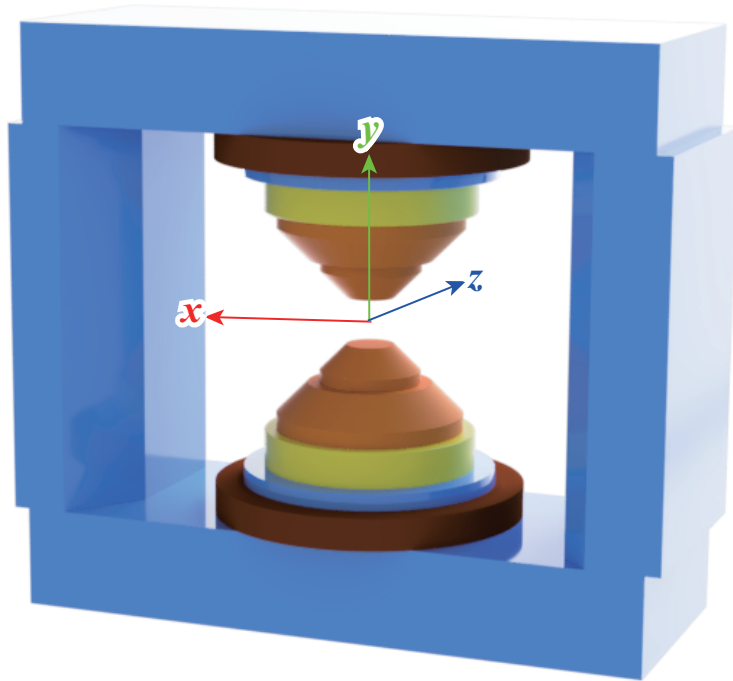
Energy range relevant for

$$\pi^- p \rightarrow \phi n$$

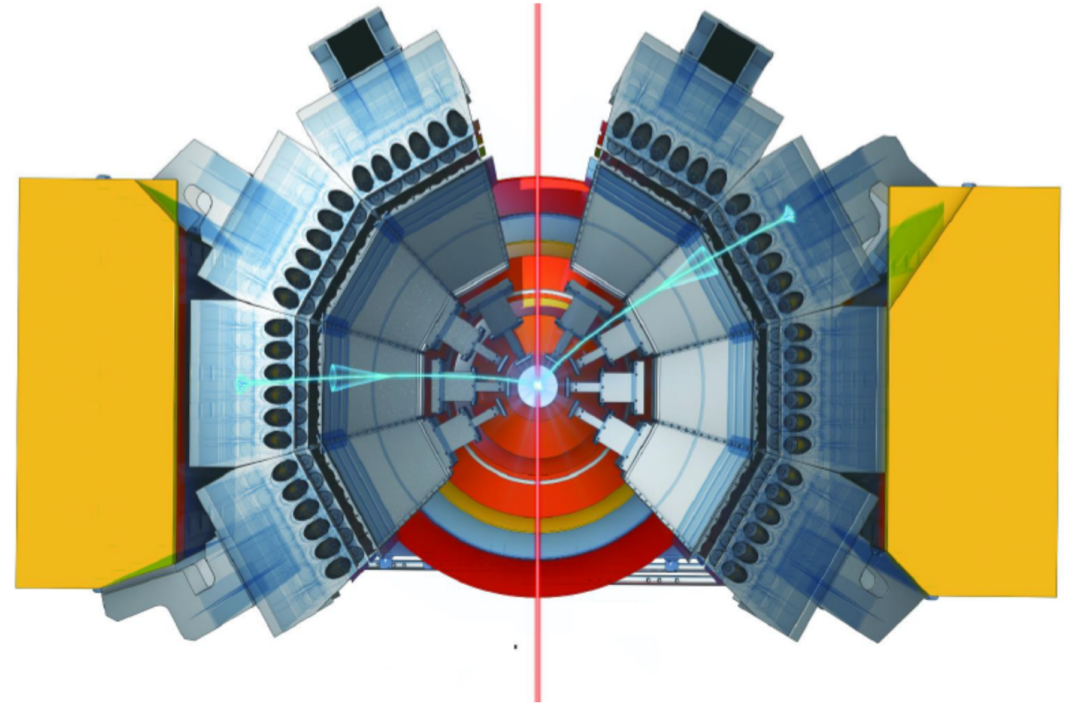
$$\pi^- p \rightarrow J/\psi n$$

E16 Experiment

$J/\psi \rightarrow e^+e^-$ and $\mu^+\mu^-$



FM Magnet

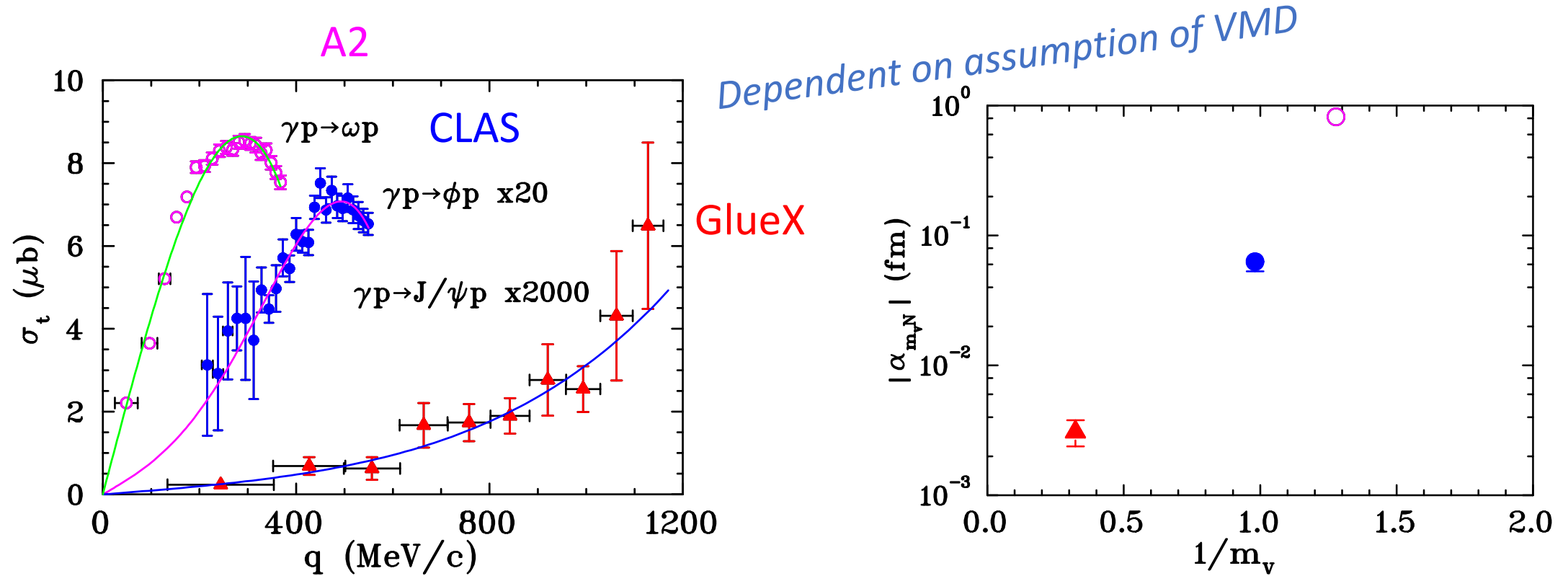


E16 Spectrometer

High-p Experiment at J-PARC

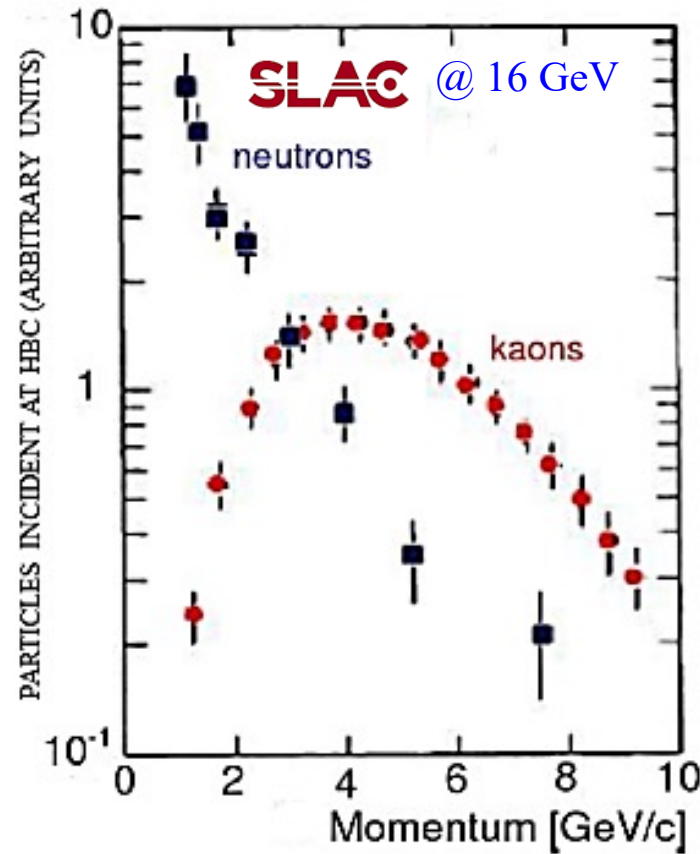
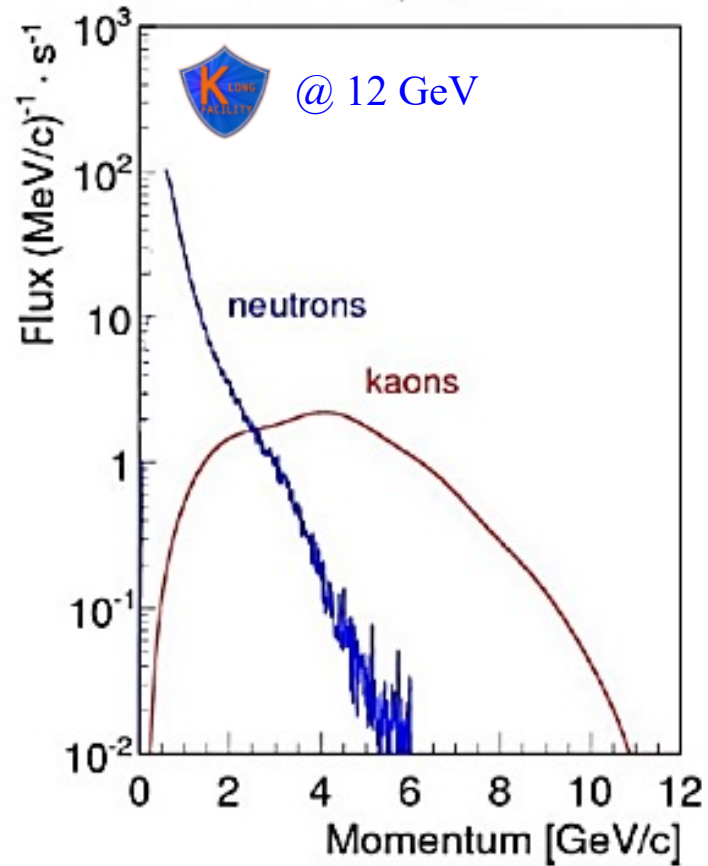
- Experimental Proposal first submitted in 2023
 - Resubmission planned to J-PARC PAC 38 in July 24
- Stage 1: 15 days (+5) to study $\pi^- p \rightarrow \phi n$
 - Beam energies of 1.8, 2.0, 2.2, 2.4 GeV
- Stage 2: additional 35 days
- Extra: Add additional beam time at higher momentum
 - $\pi^- p \rightarrow J/\psi n$
 - Study production cross section near threshold
 - Search for isospin partners of P_c^+ states
 - $J/\psi N$ scattering length

Scaling of VM/proton scattering length



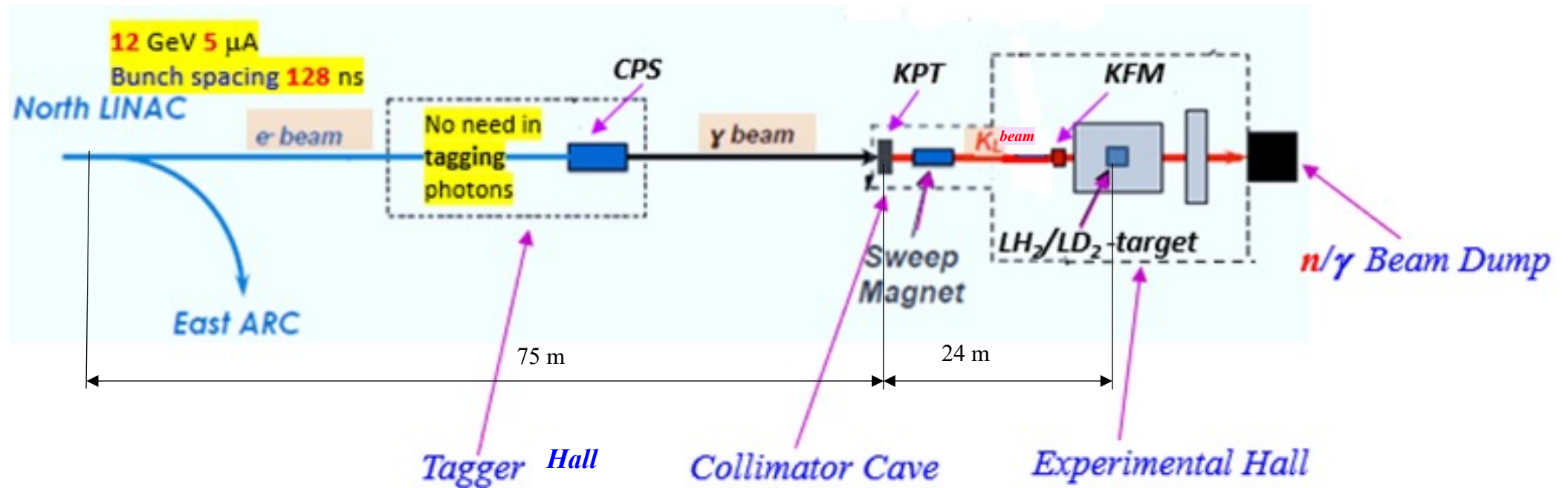
Strakovsky, Pentchev, Titov, PRC 101, 045201 (2020)

Future K-Long Facility at Jefferson Lab





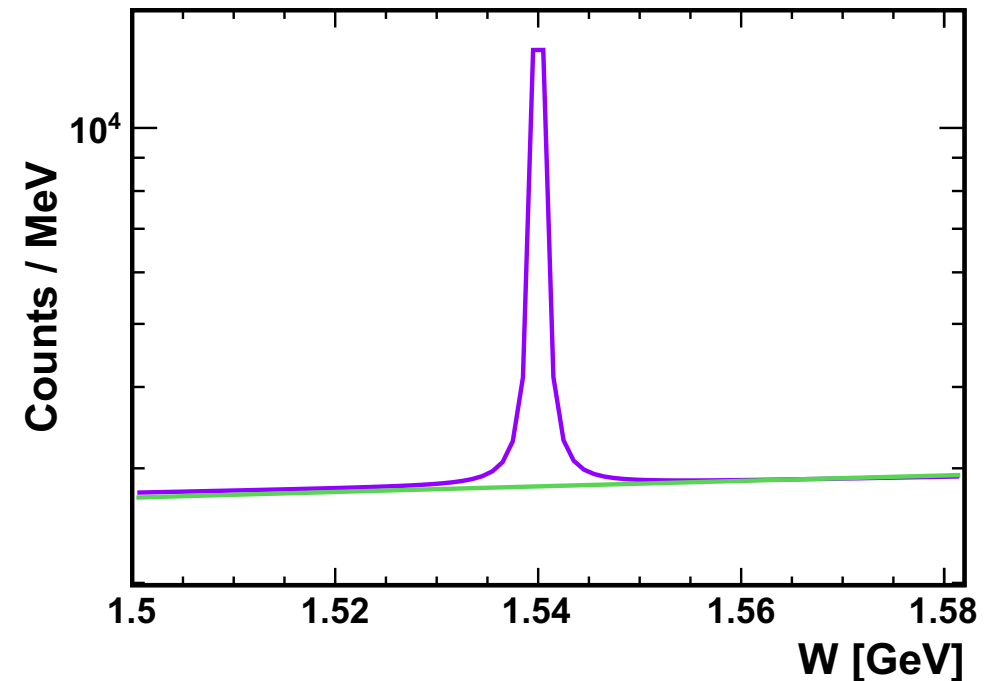
Future K-Long Facility at Jefferson Lab



KLF can search for 5q states in a 2→2 process

$$K_L p \rightarrow \Theta^+ \rightarrow K^+ n$$

Hyperon	Reaction
Σ^*	$K_L p \rightarrow \pi \Sigma^* \rightarrow \pi \pi \Lambda$
Λ^*	$K_L p \rightarrow \pi \Lambda^* \rightarrow \pi \pi \Sigma$
Ξ^*	$K_L p \rightarrow K \Xi^* \rightarrow \pi K \Xi^*$
Ω^*	$K_L p \rightarrow K^+ K^+ \Omega^*$



Amaryan, Hirama, Jido, Strakovsky, Mod. Phys. Lett. A 2450063 (2024)

Hall D Short Range Correlations / Color Transparency Experiment

E12-19-003

Jefferson Lab Hall D (GlueX)

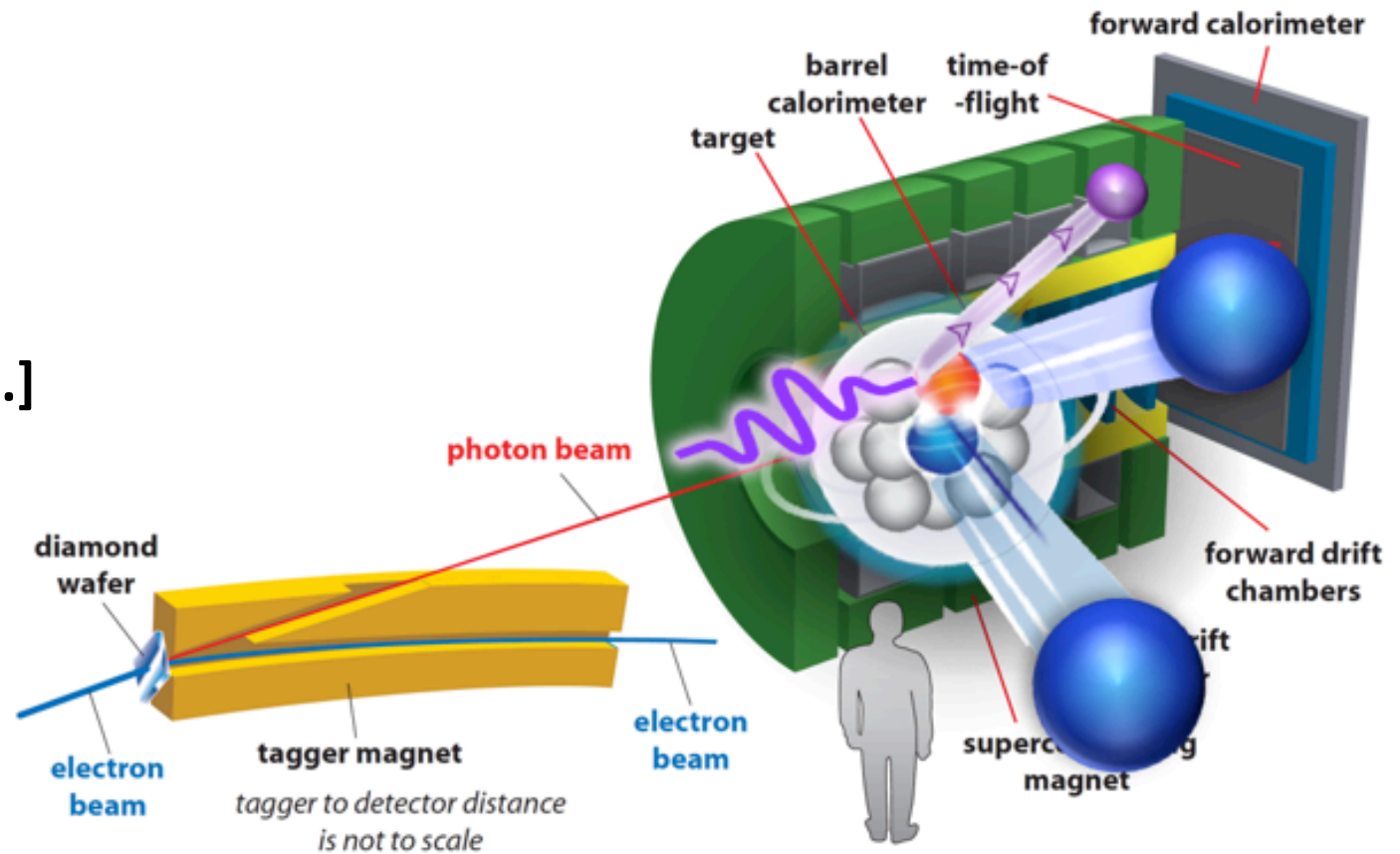
Nov.–Dec., 2021

Targets **Luminosity [$\text{pb}^{-1} \text{nucl.}$]**

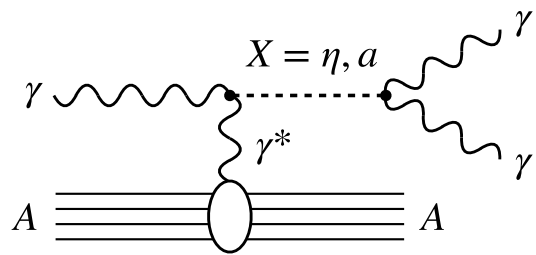
d 32.5

^4He 60.4

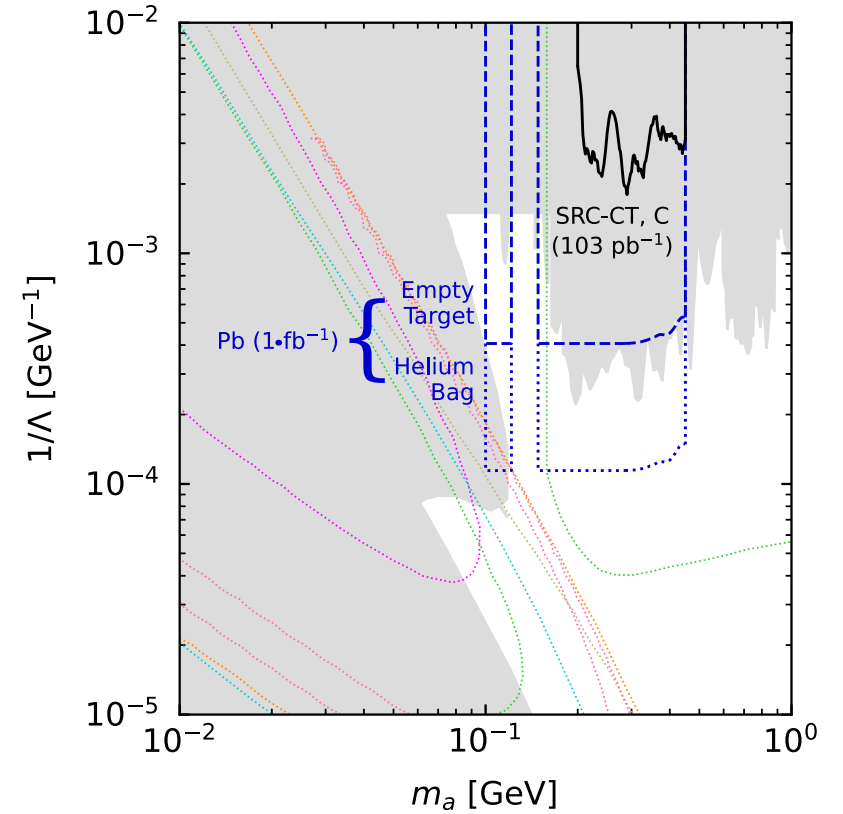
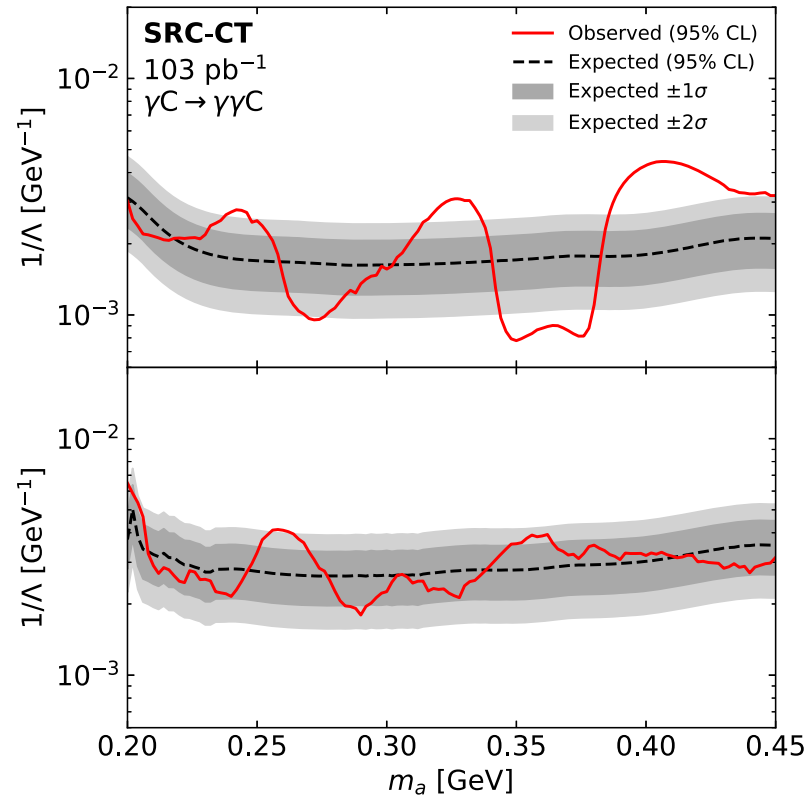
^{12}C 93.5



First paper: Axion Like Particle Search



Primakoff Production



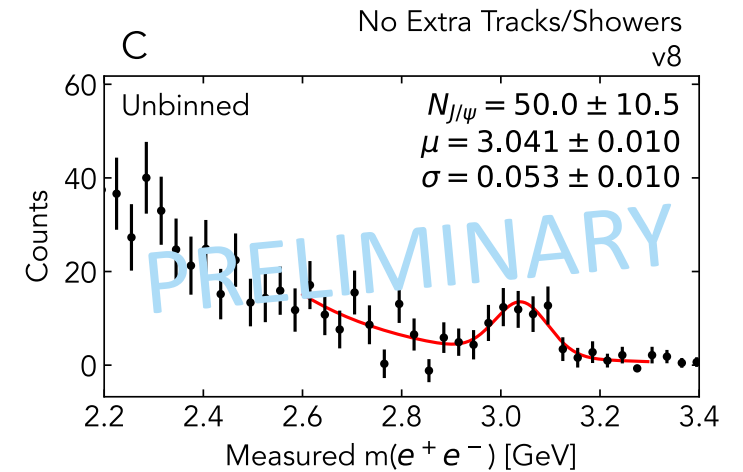
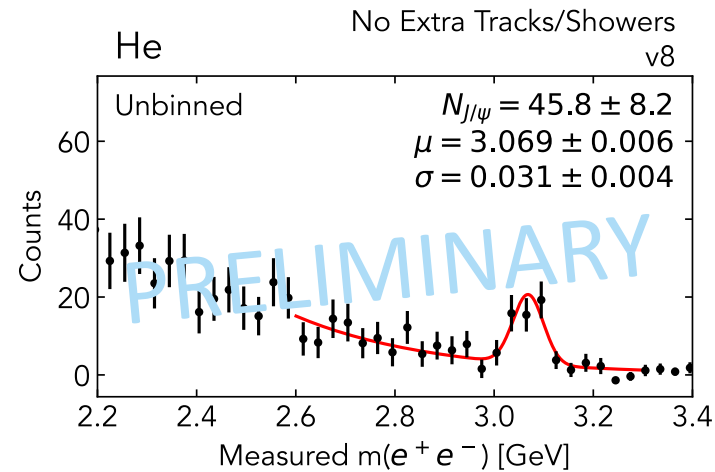
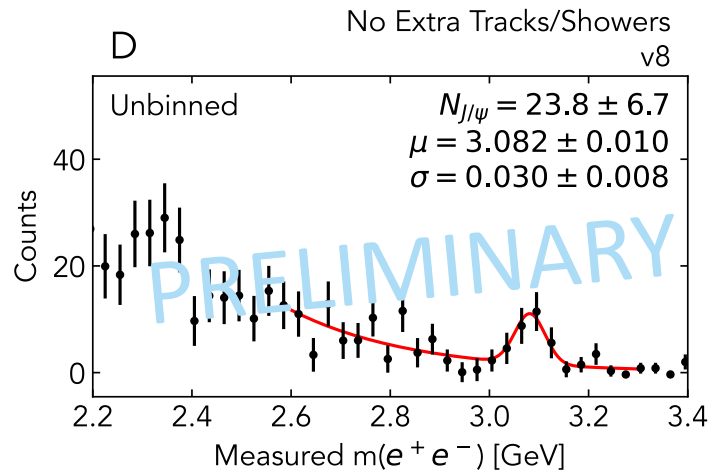
Incoherent J/ψ production from nuclei

Results coming soon!



Jackson Pybus
(MIT)

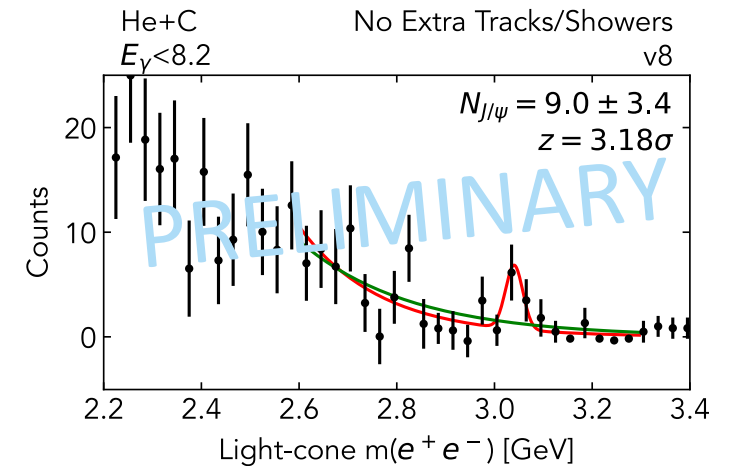
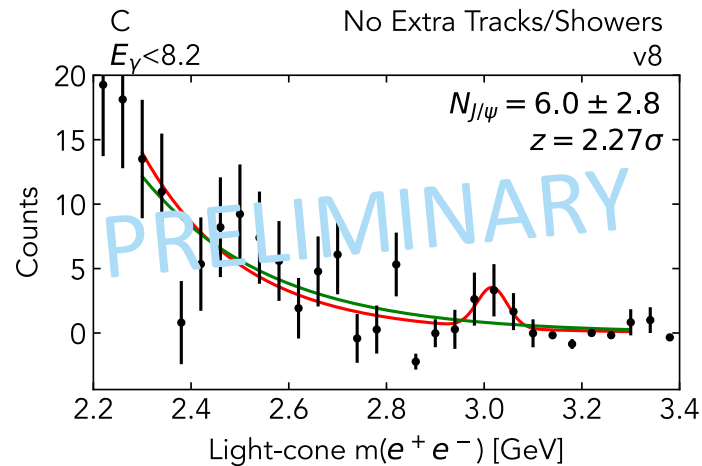
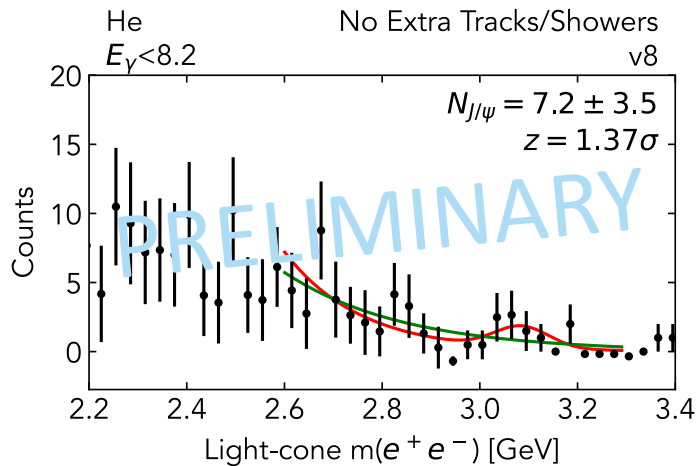
$$\gamma A \rightarrow J/\psi p (A - 1) \rightarrow e^+ e^- p (X)$$



Incoherent J/ψ production from nuclei

Results coming soon!

Evidence of subthreshold production: $E_\gamma < 8.2 \text{ GeV}$



Summary

- Search for the LHCb P_c^+ states in GlueX
 - No peak observed in the GlueX data
 - Dip-like structure is consistent with destructive interference between resonance and background.
 - Cusp-effects are expected near open charm thresholds
- High-p Experimental Proposal at J-PARC
 - Opportunity for high statistics for $\pi^- p \rightarrow J/\psi n$ reaction
 - Search for other isospin partners of LHCb states
 - Probe dynamics of $c\bar{c}$ production
 - Resubmission of $\pi^- p \rightarrow \phi n$ proposal to PAC38 in July, 2024