Spectroscopy Outlook

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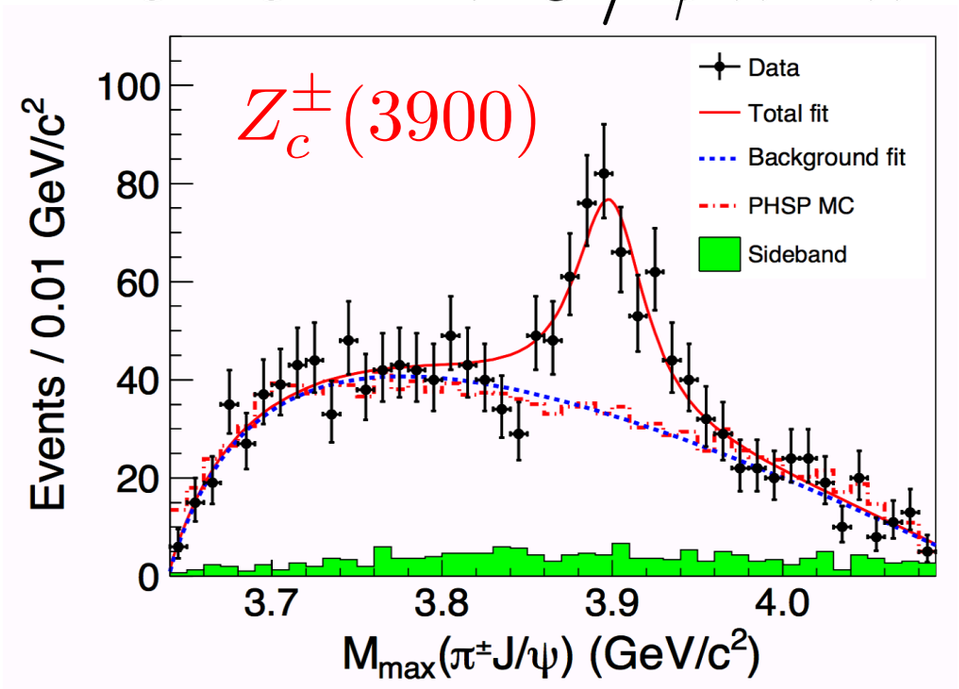
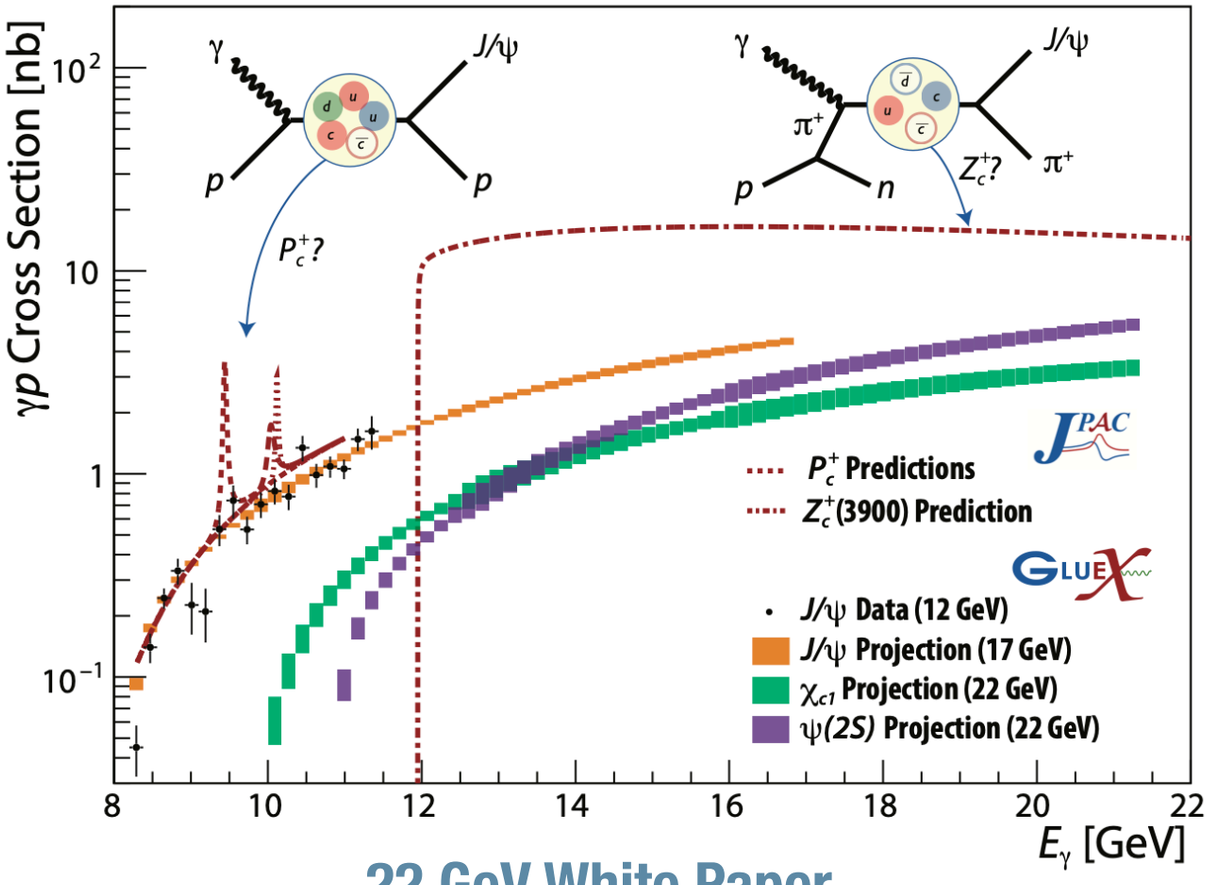
WILLIAM & MARY
CHARTERED 1693

Exotic states with $c\bar{c}$

- Thresholds for XYZ states open just above 12 GeV
- For example, Z_c enhanced in 22 GeV region, consistent with COMPASS upper limit

$$e^+e^- \to J/\psi\pi^+\pi^-$$





22 GeV White Paper

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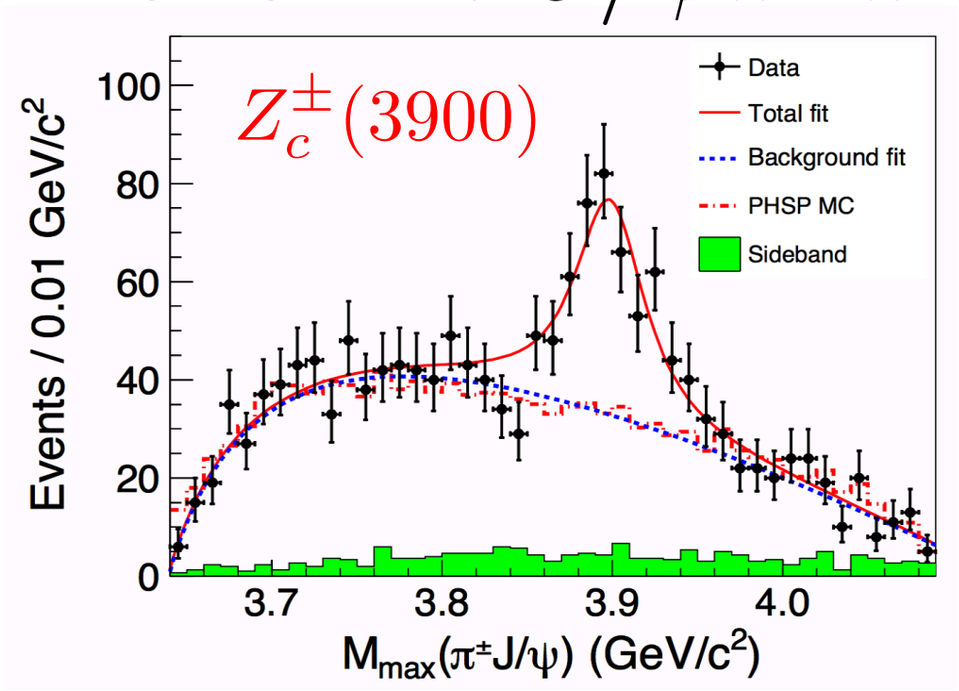

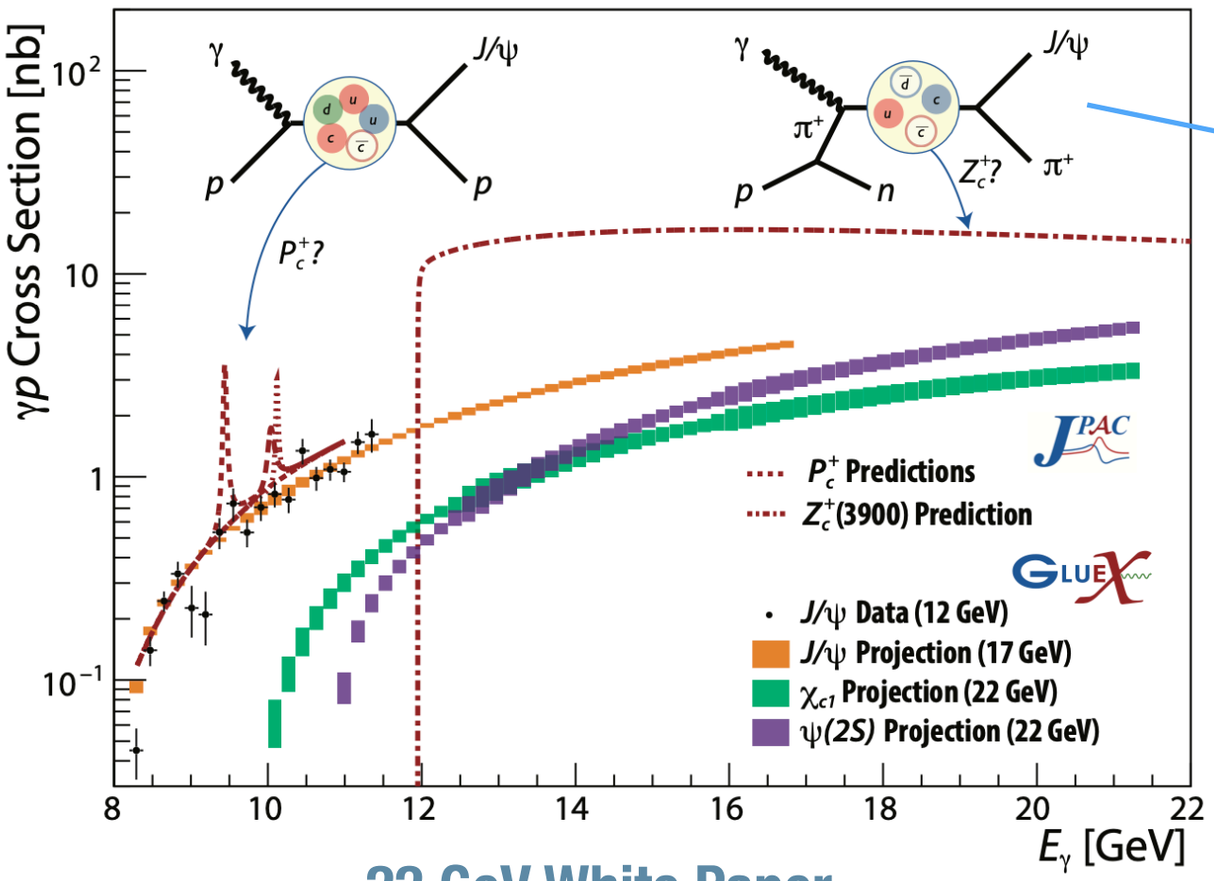

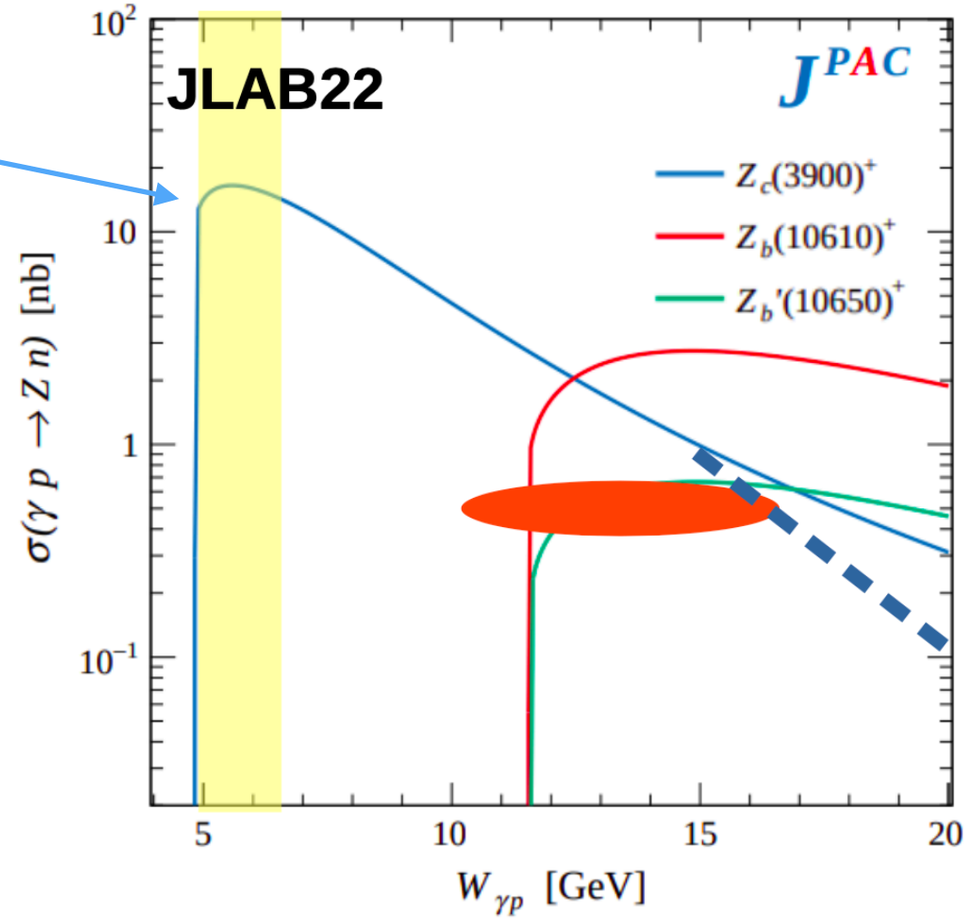

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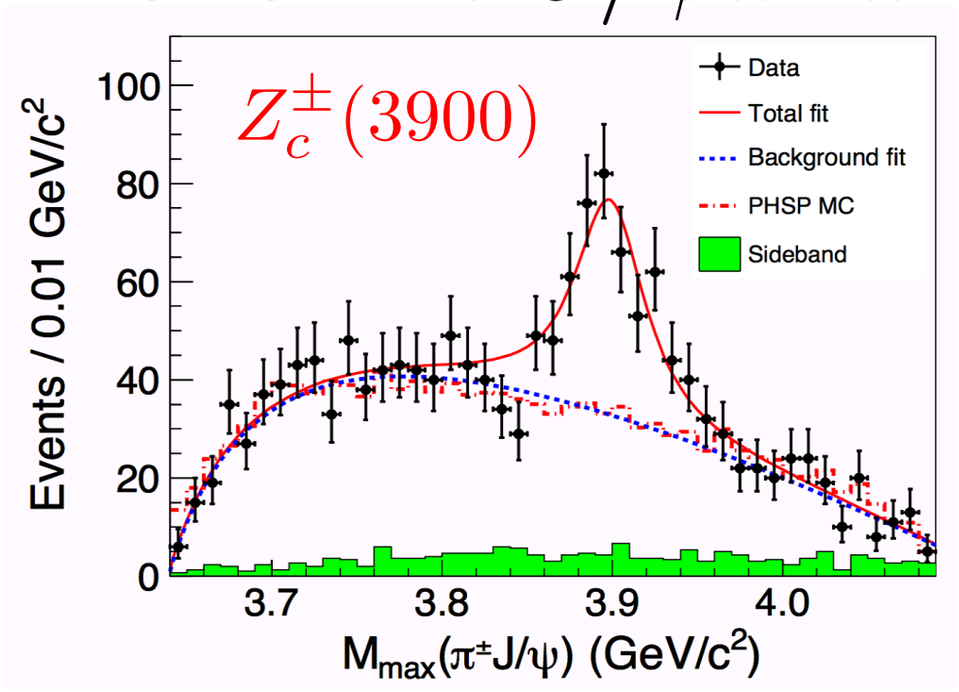
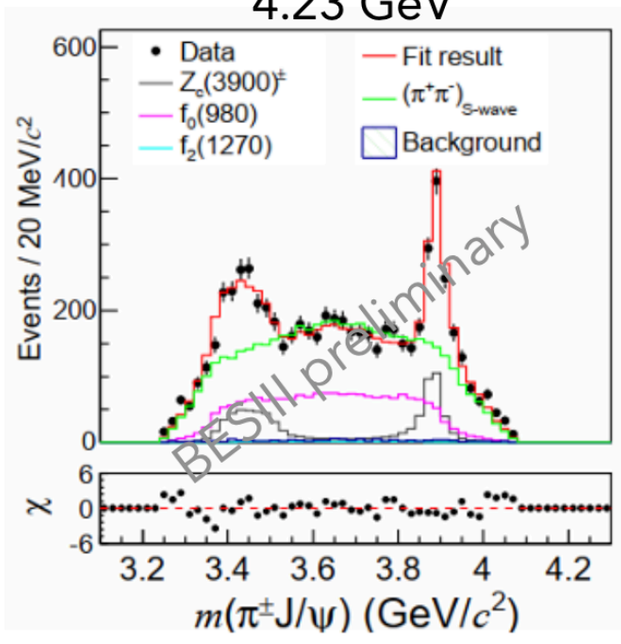


- Keep in mind, field is still moving forward at BESIII, LHCb, etc.

More data

4.23 GeV



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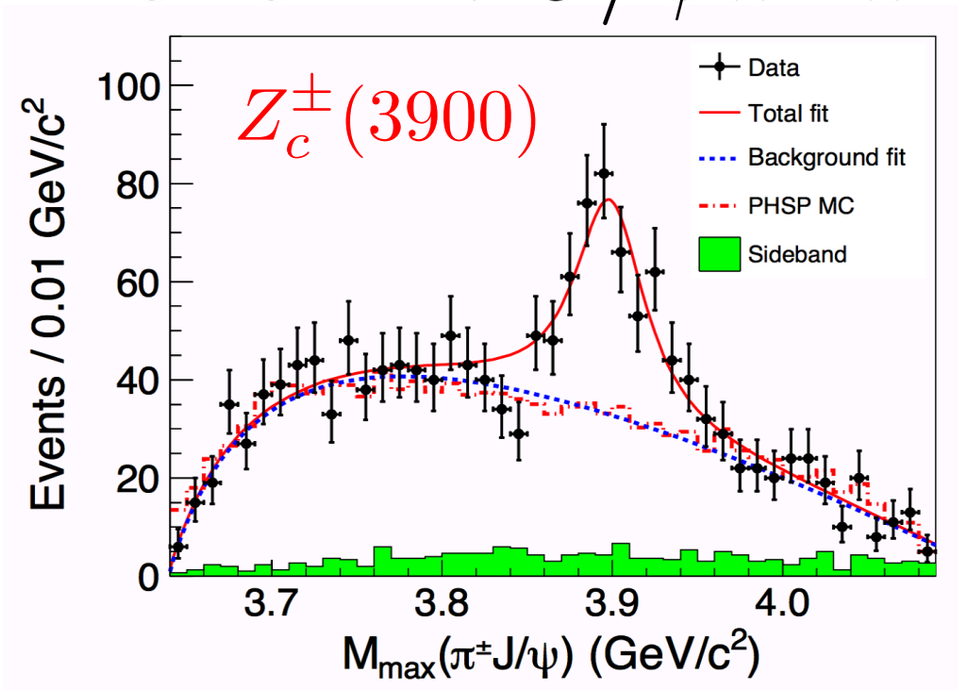

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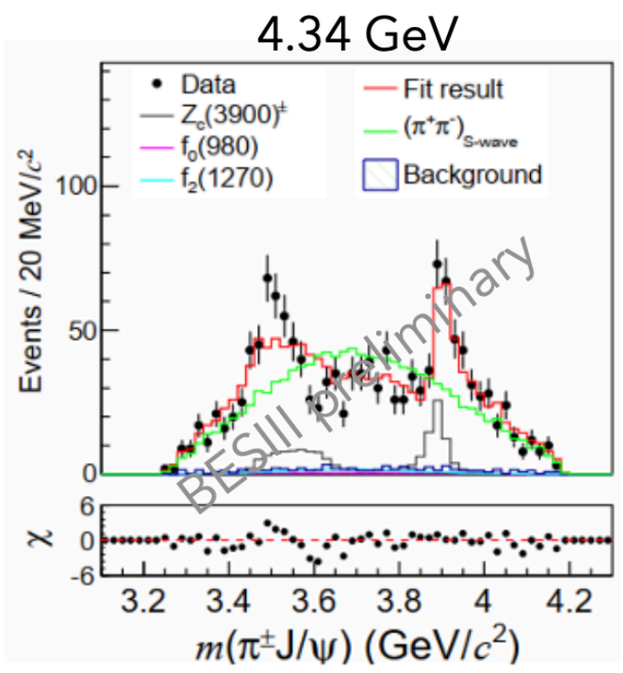
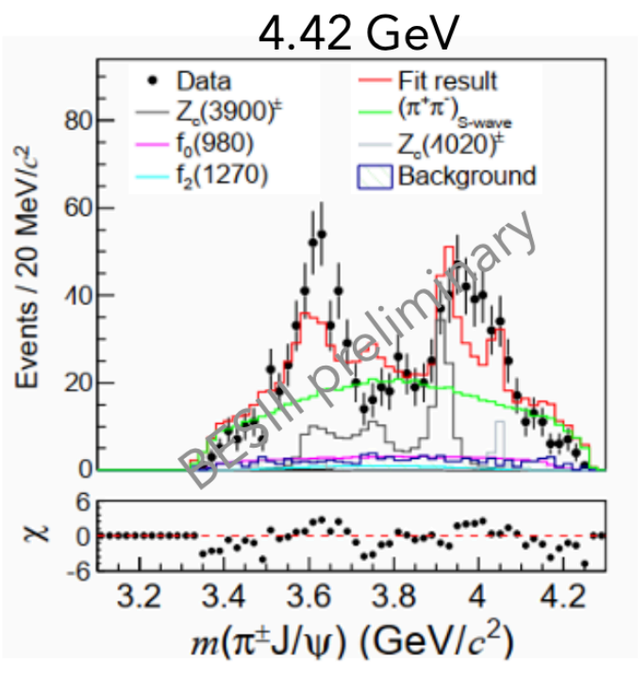
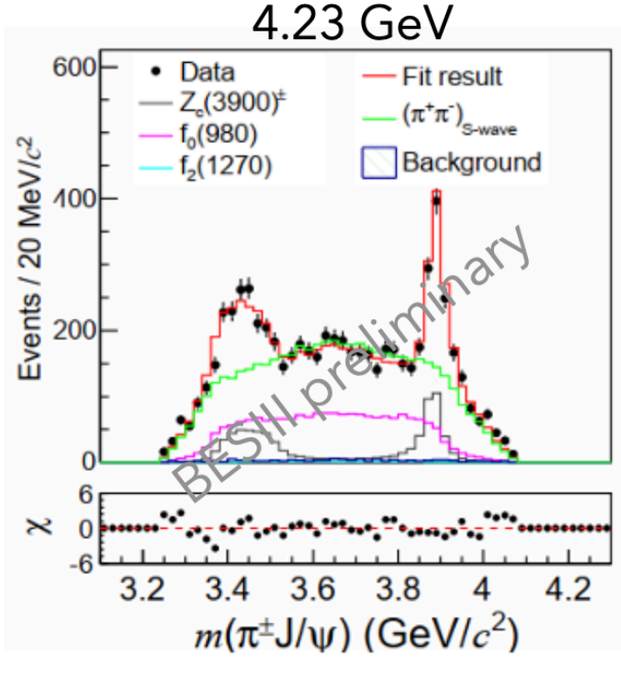




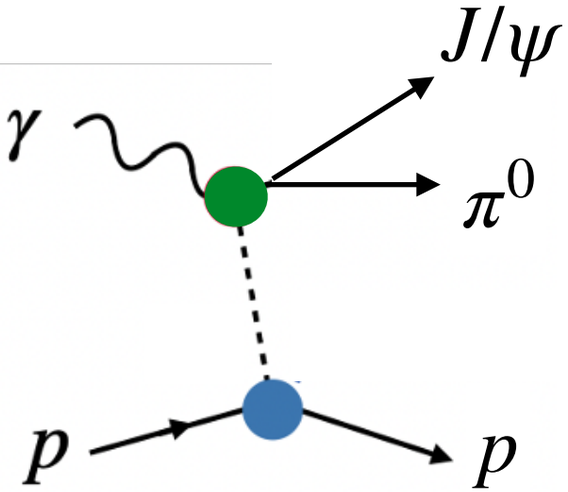
Higher energy

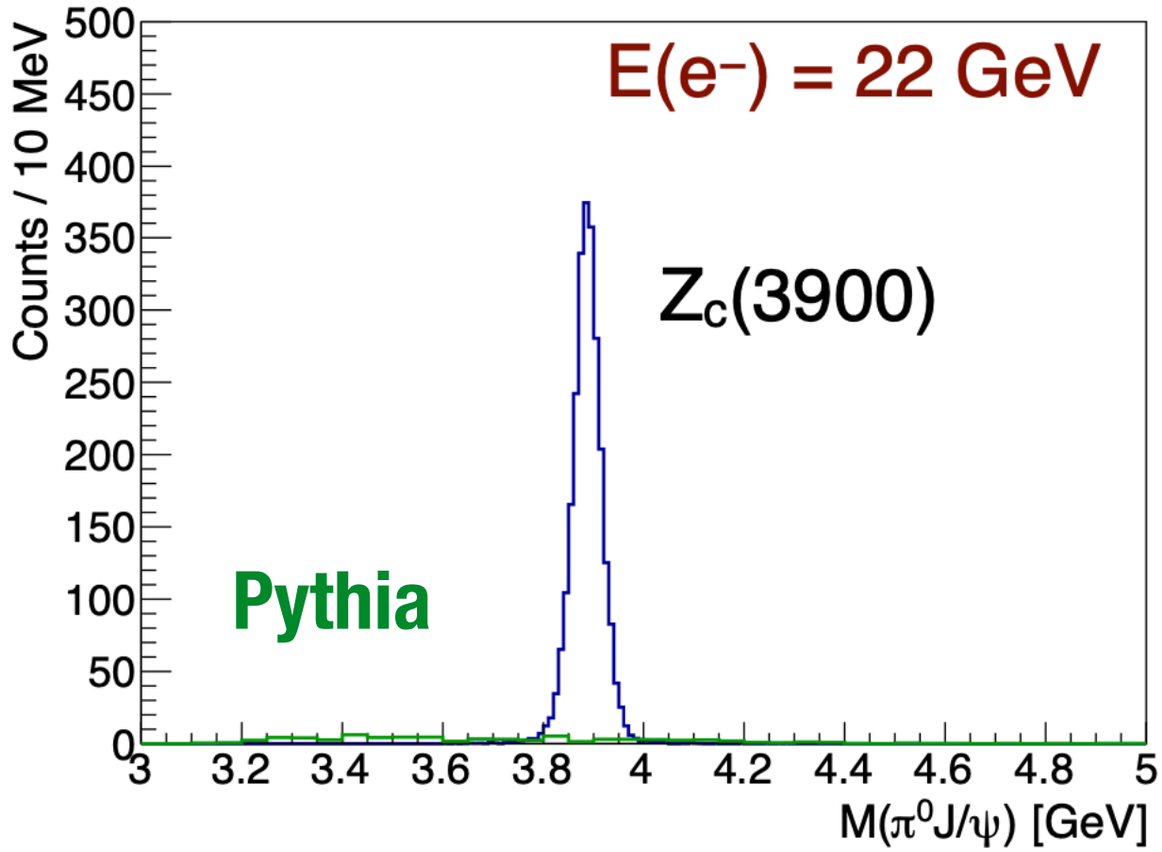


Next steps: non-resonant background

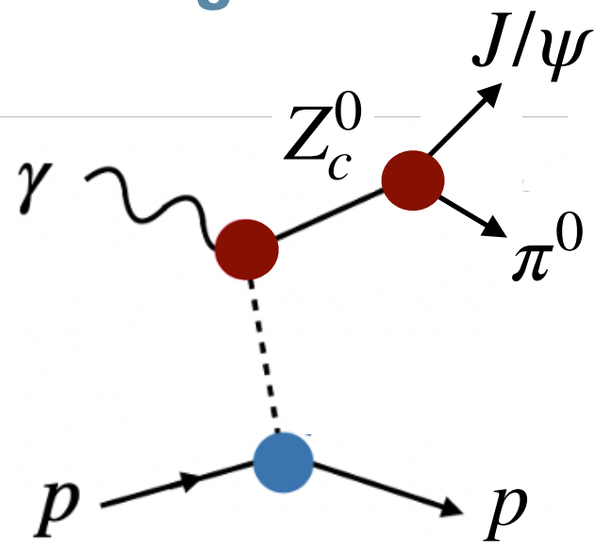
$$\gamma p \to J/\psi \pi^0 p, \;\; J/\psi \to e^+ e^-$$

Non-resonant





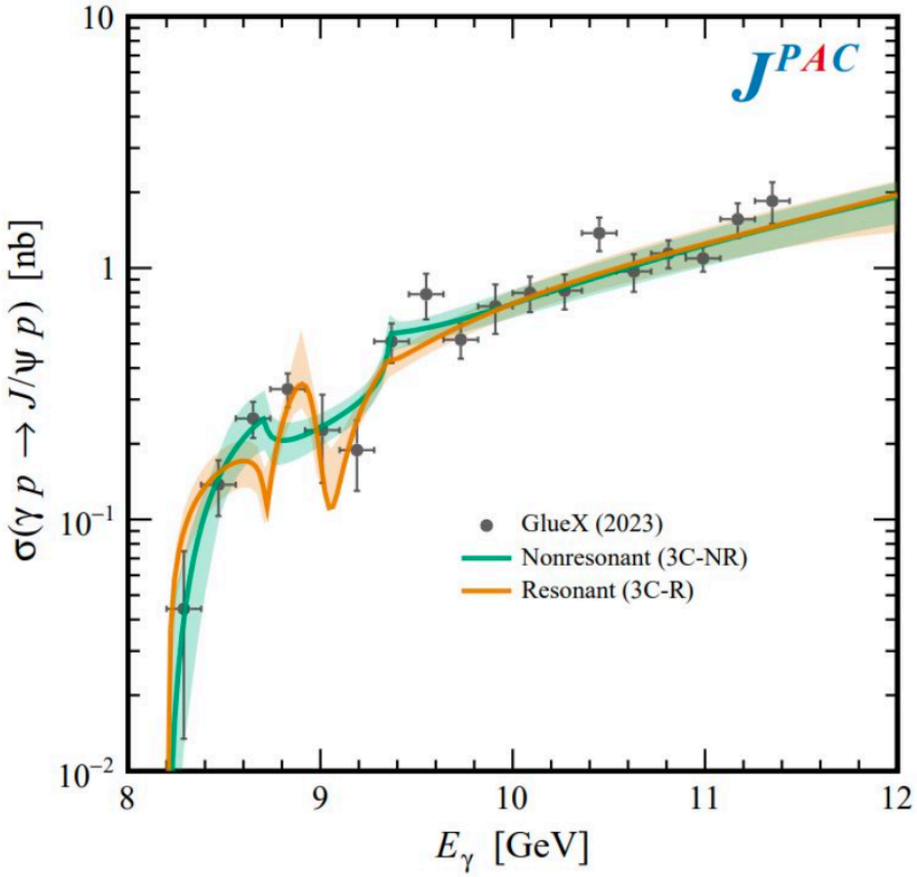
Signal MC



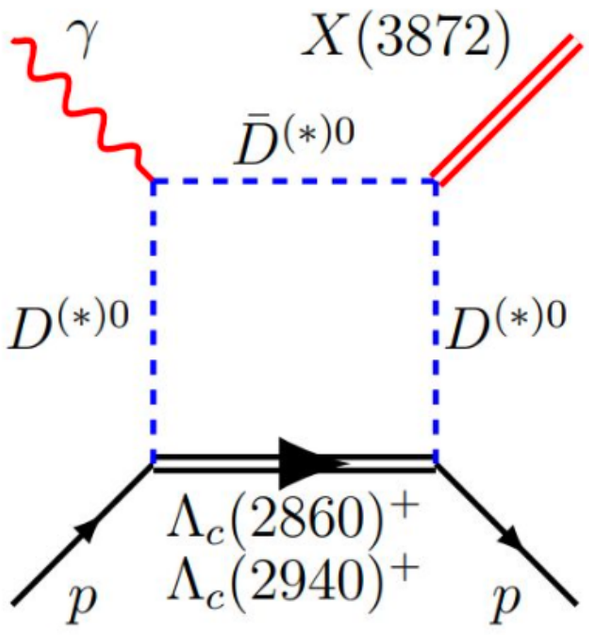
- Exclusive reconstruction of signal MC show clear structure with limited particle mis-ID backgrounds
- However, expect background from non-resonant production that should be calculated. Use previous measurements of couplings, estimates from COMPASS UL or existing data from GlueX

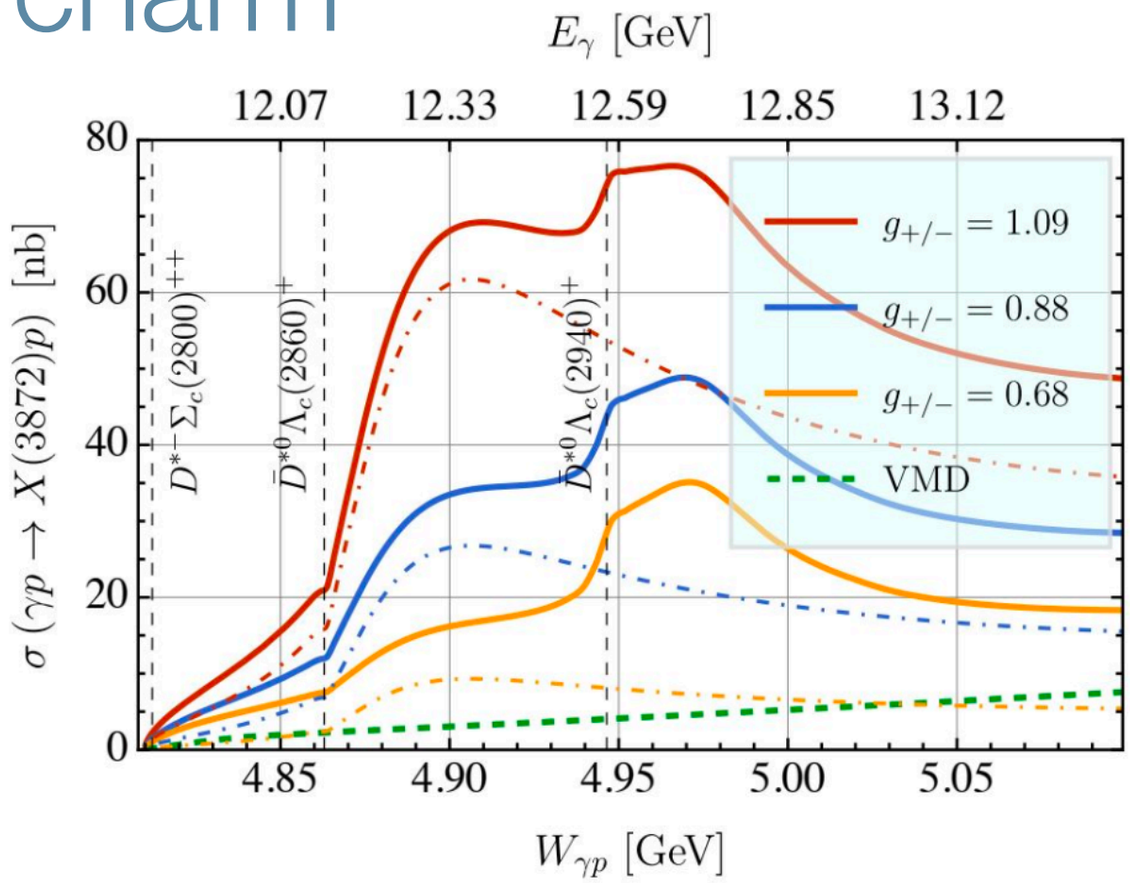
Next steps: quantifying interpretation

- Any observation would be a critical confirmation of the resonance picture, but what about non-observation?
- Current 12 GeV data on J/ψ is consistent with weak resonant (P_c) and non-resonant interpretation, limiting models for nature of P_c
- For 22 GeV we need quantitative interpretation of photocouplings for models of Z_c microscopic structure?
  - How to connect this with Lattice QCD or QCD-inspired models?



Next steps: open charm





- Open charm continues to play important role interpretation of existing observations and can produce non-trivial structure
- What can we learn from 12 GeV? Studies with existing GlueX data to at least set an upper limit on ground state $\gamma p \to \Lambda_c D$
- Would an upgraded detector enable a robust 22 GeV program?

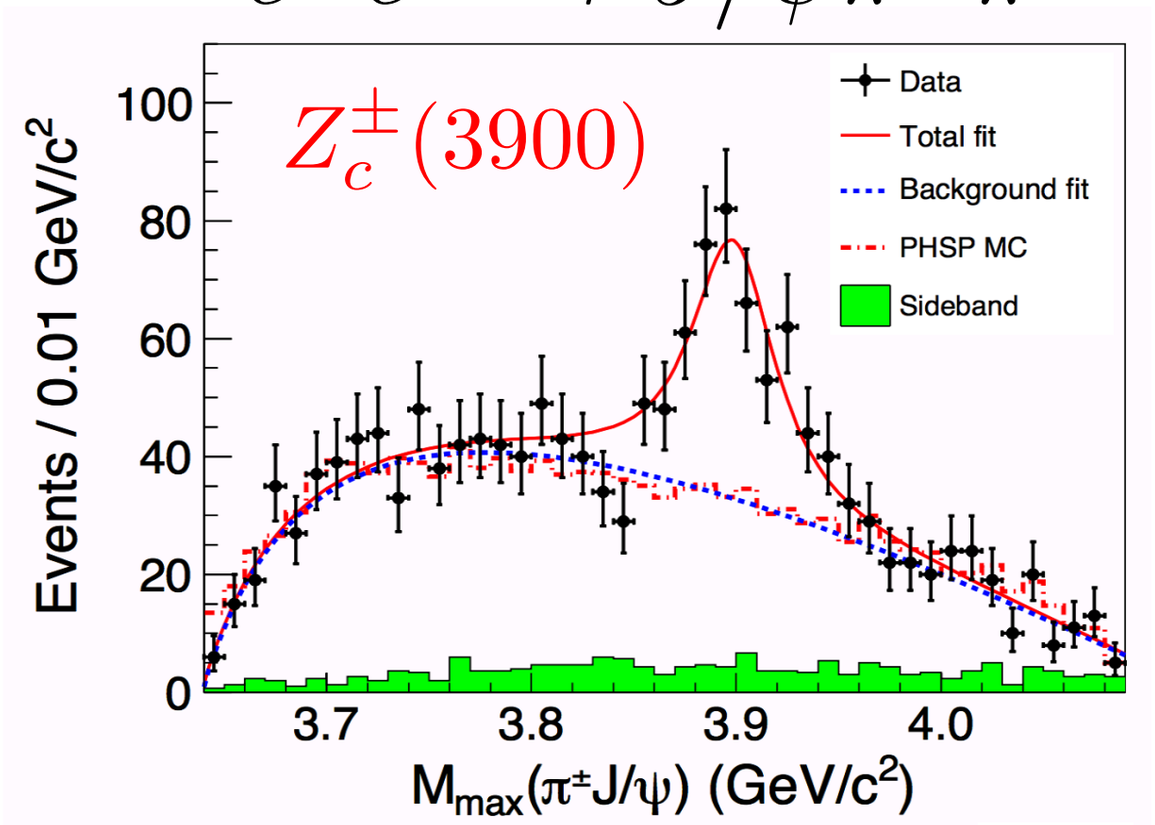
Summary (of the outlook)

- Spectroscopy of exotic states with $c\bar{c}$ remains a "simple" argument for the energy upgrade
- Challenges:
  - Reasonable non-resonant background models
  - Quantifying interpretation of potential null result
  - Reconstruction of open charm channels
- The next steps to address these challenges are clear, but will take some time

Backup

Charged tetraquark candidates: Z_c

$$e^+e^- \to J/\psi\pi^+\pi^-$$

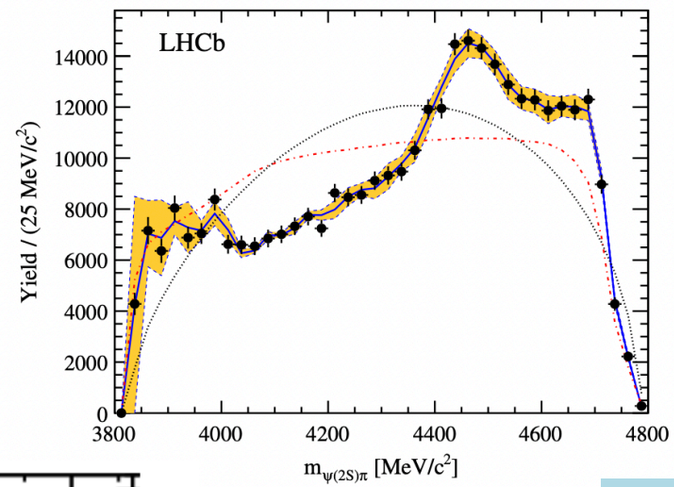


PRL 110, 252001 (2013) BESIII

PRL 110, 252002 (2013) BELLE

$Z_c^-(4430)$

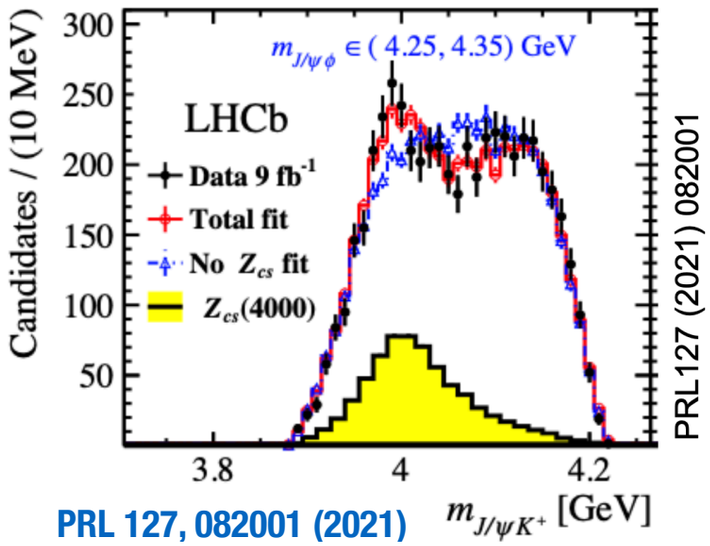
$$B^0 \to \psi(2S)K^+\pi^-$$



PRD 92, 112009 (2015) LHCb

$Z_{cs}^+(4000)$

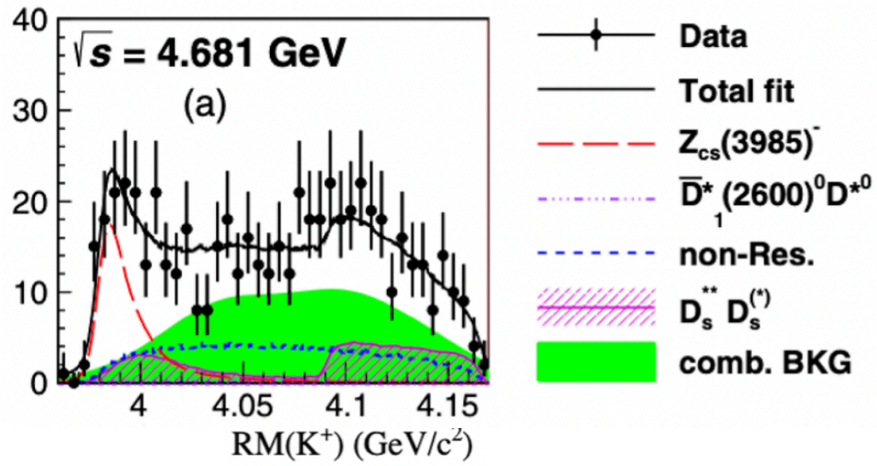
$$B^+ \to J/\psi\phi K^+$$



PRL 127, 082001 (2021)

$Z_{cs}^+(3985)$

$$e^+e^- \to K^+D_s^-X$$

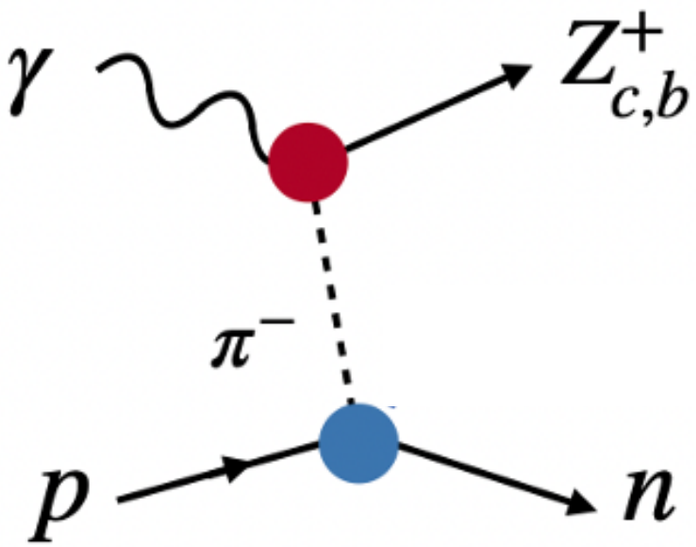


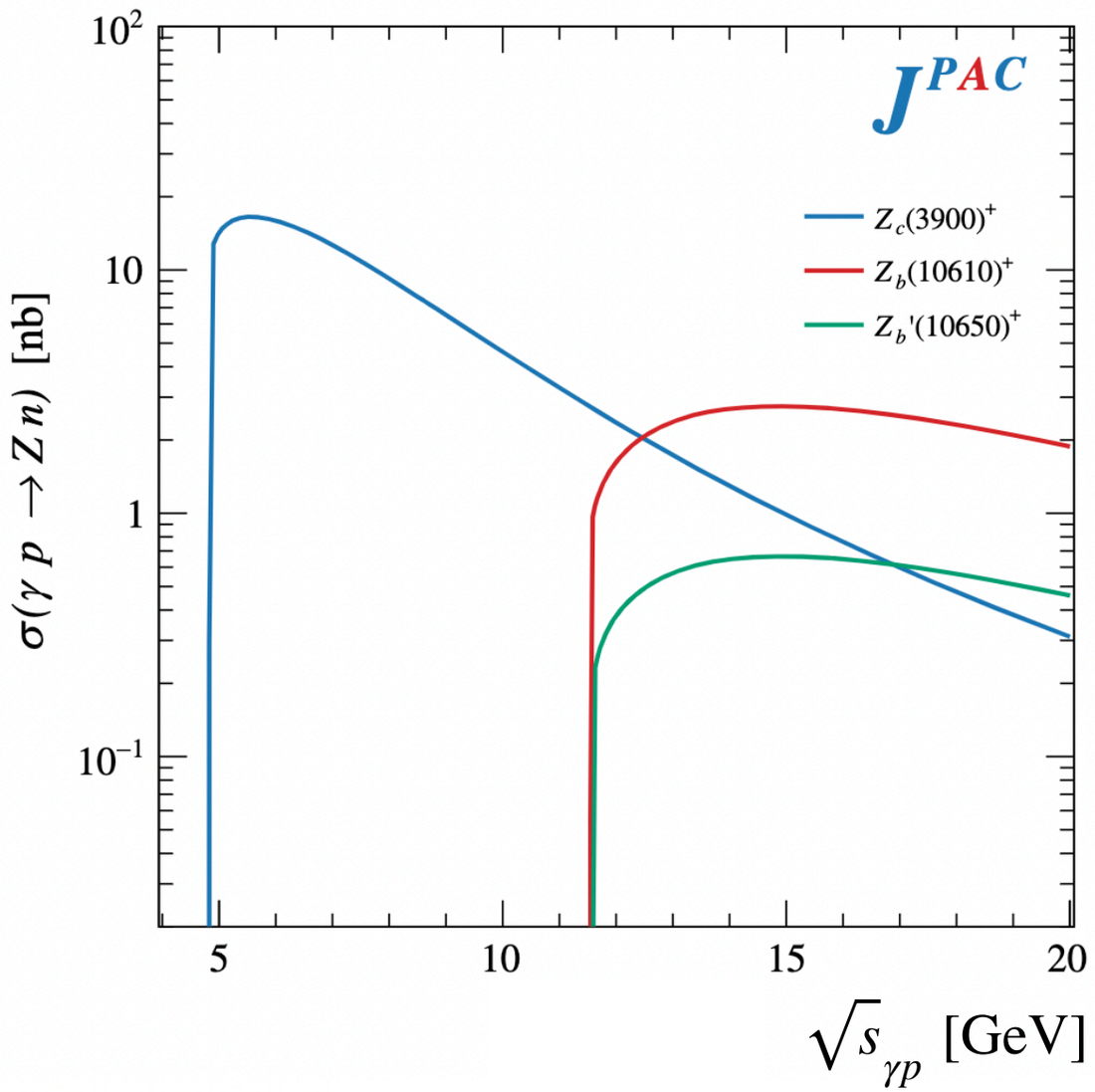
- Many observations of charged Z_c $(c\bar{c}q\bar{q})$ and Z_{cs} $(c\bar{c}s\bar{q})$
- Production mechanism dependent masses and widths (e^+e^- vs B decay)

Photoproduction of $Z_c^+(3900)$

Future

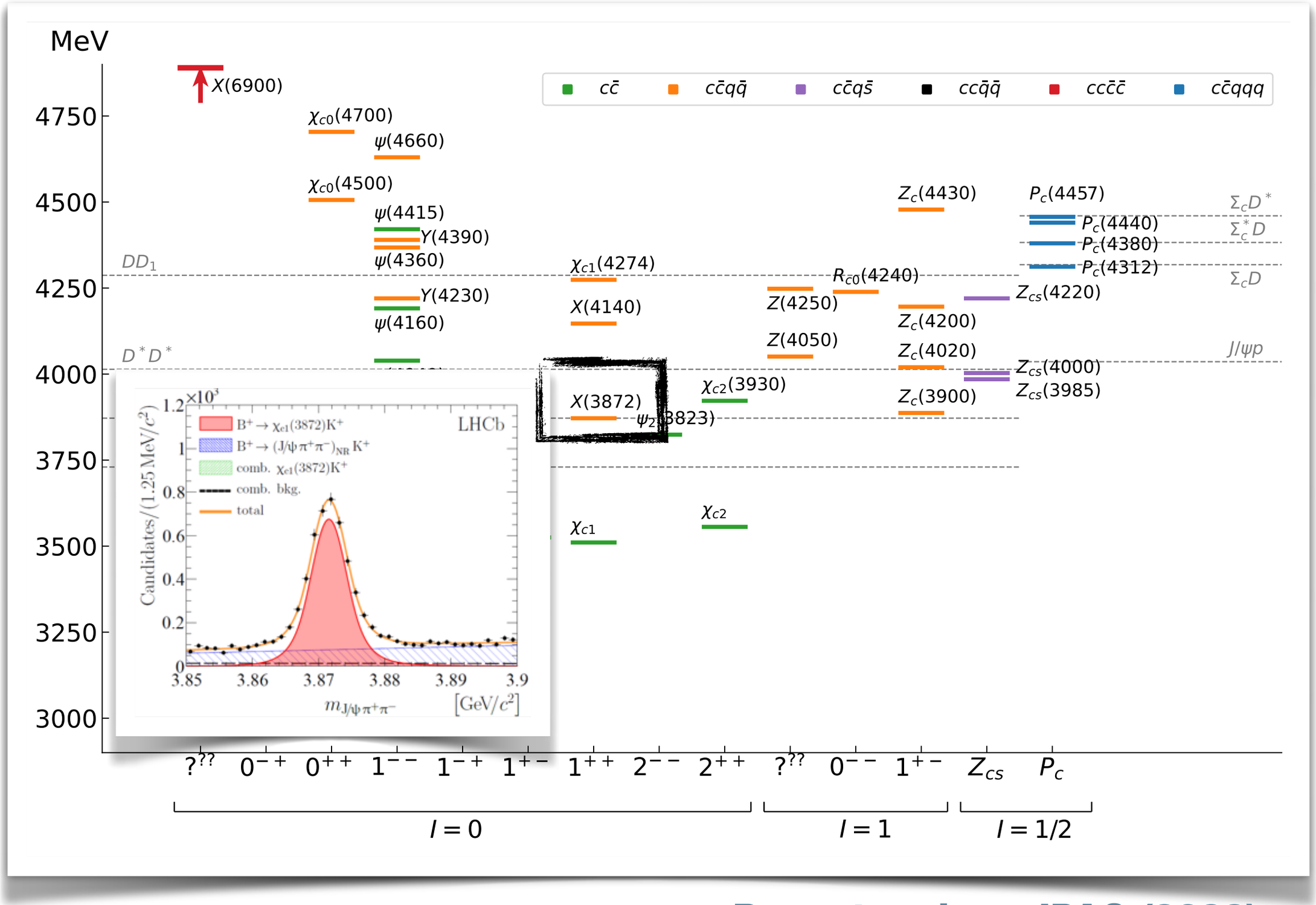
- Alternative production mechanism: free of rescattering effects and sensitive to photo couplings
- Same production mechanism near threshold (π exchange) studied with light quarks in GlueX and CLAS12





JPAC : PRD 102, 114010 (2020)

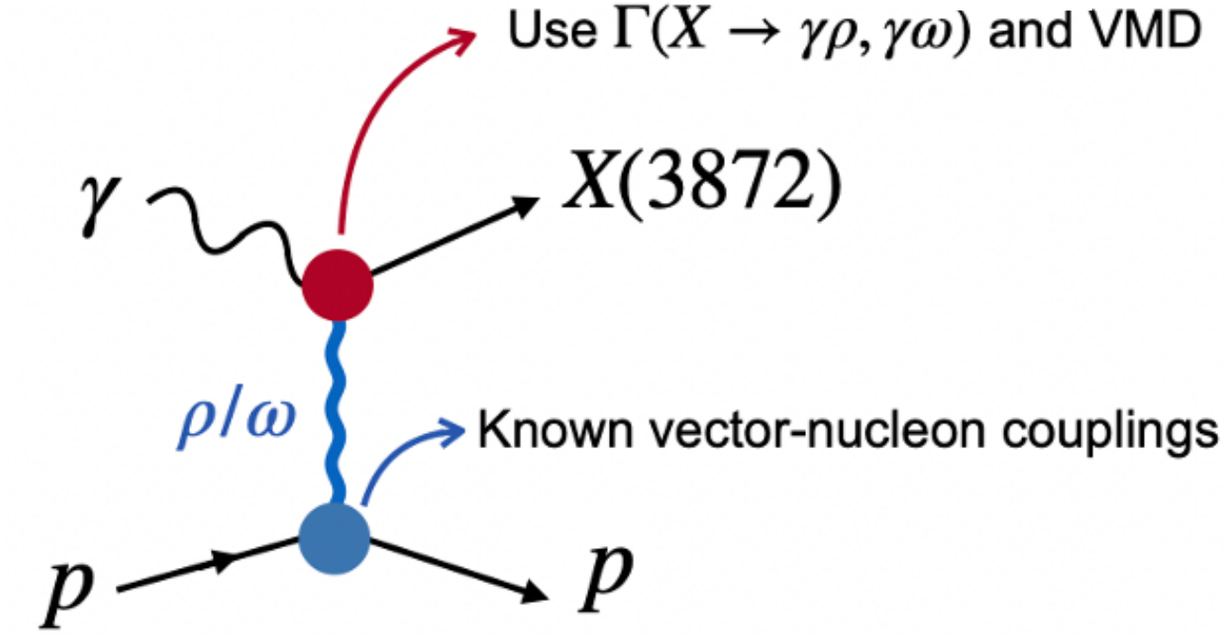
XYZ reminder: $X(3872)$ or $\chi_{c1}(3872)$

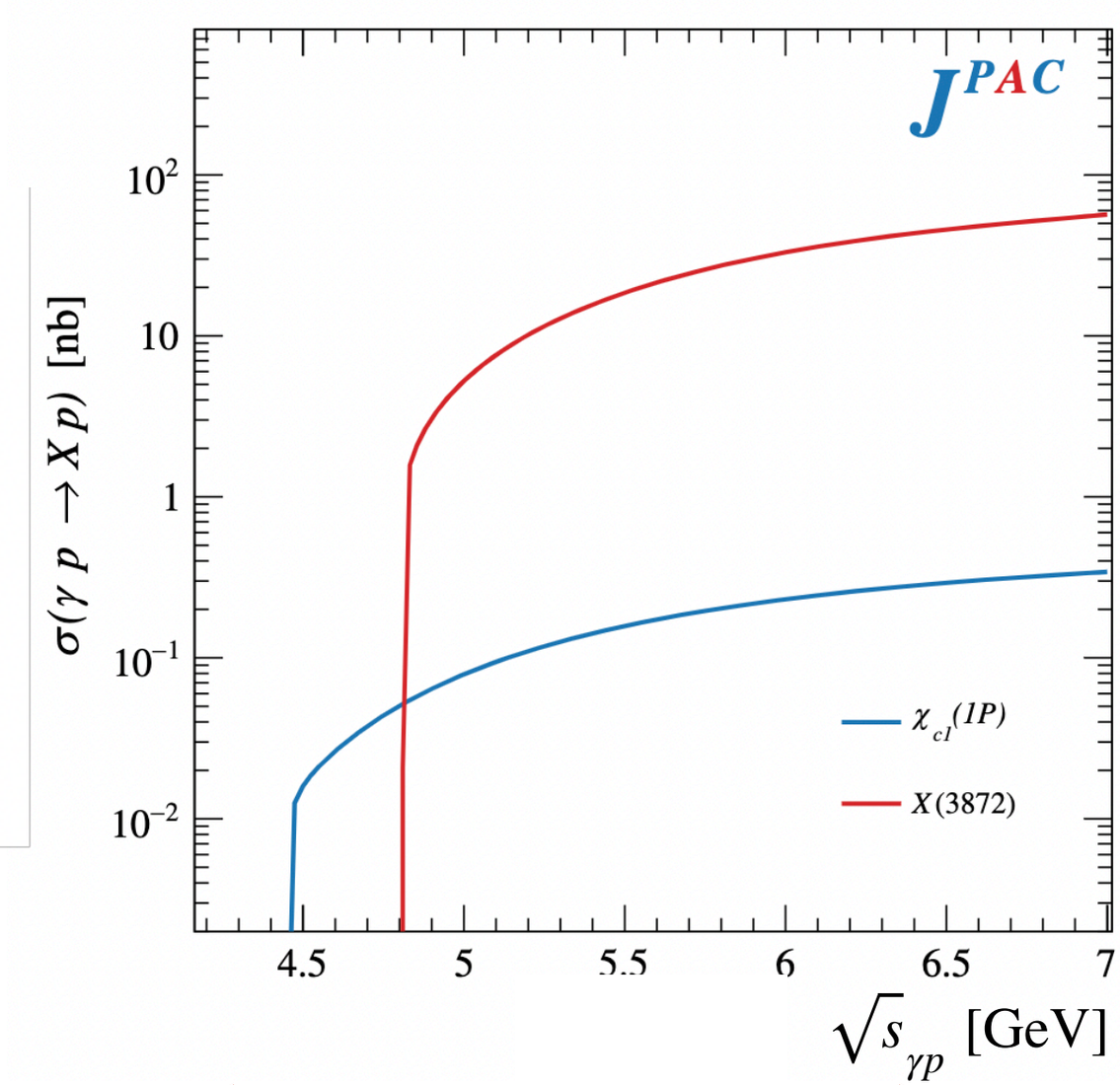


Recent review: JPAC (2022)

Photoproduction of $X(3872)$

JPAC: PRD 102, 114010 (2020)





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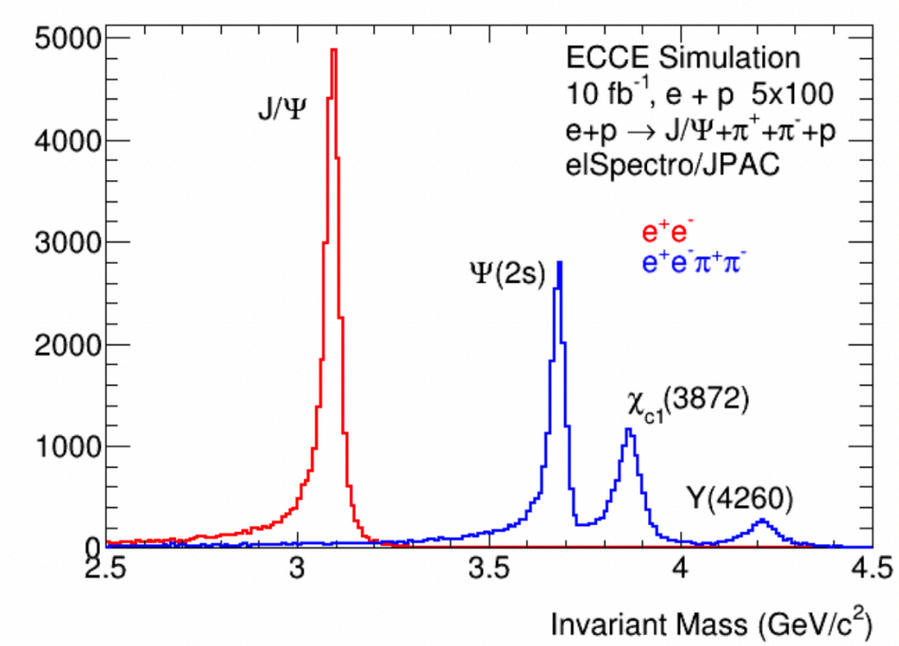
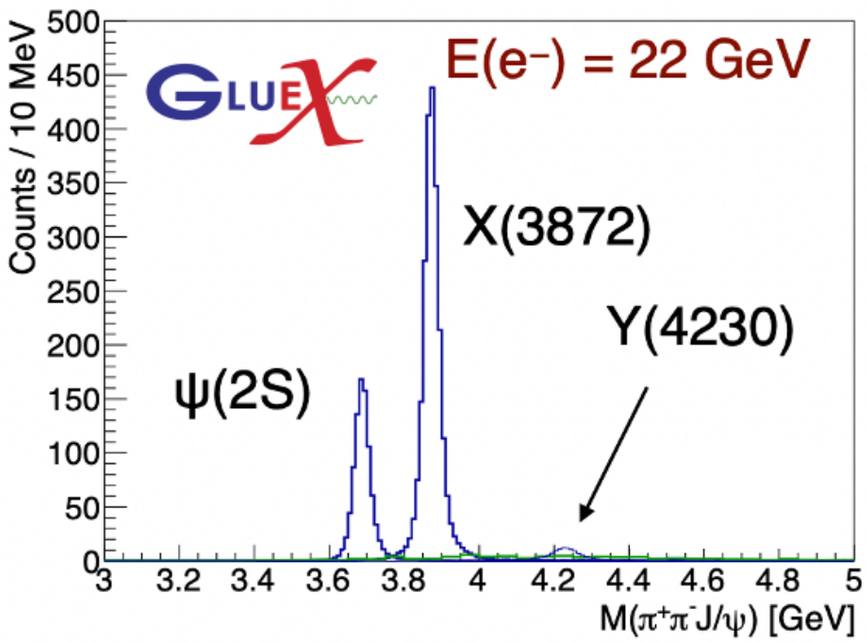
Jefferson Lab 22 GeV

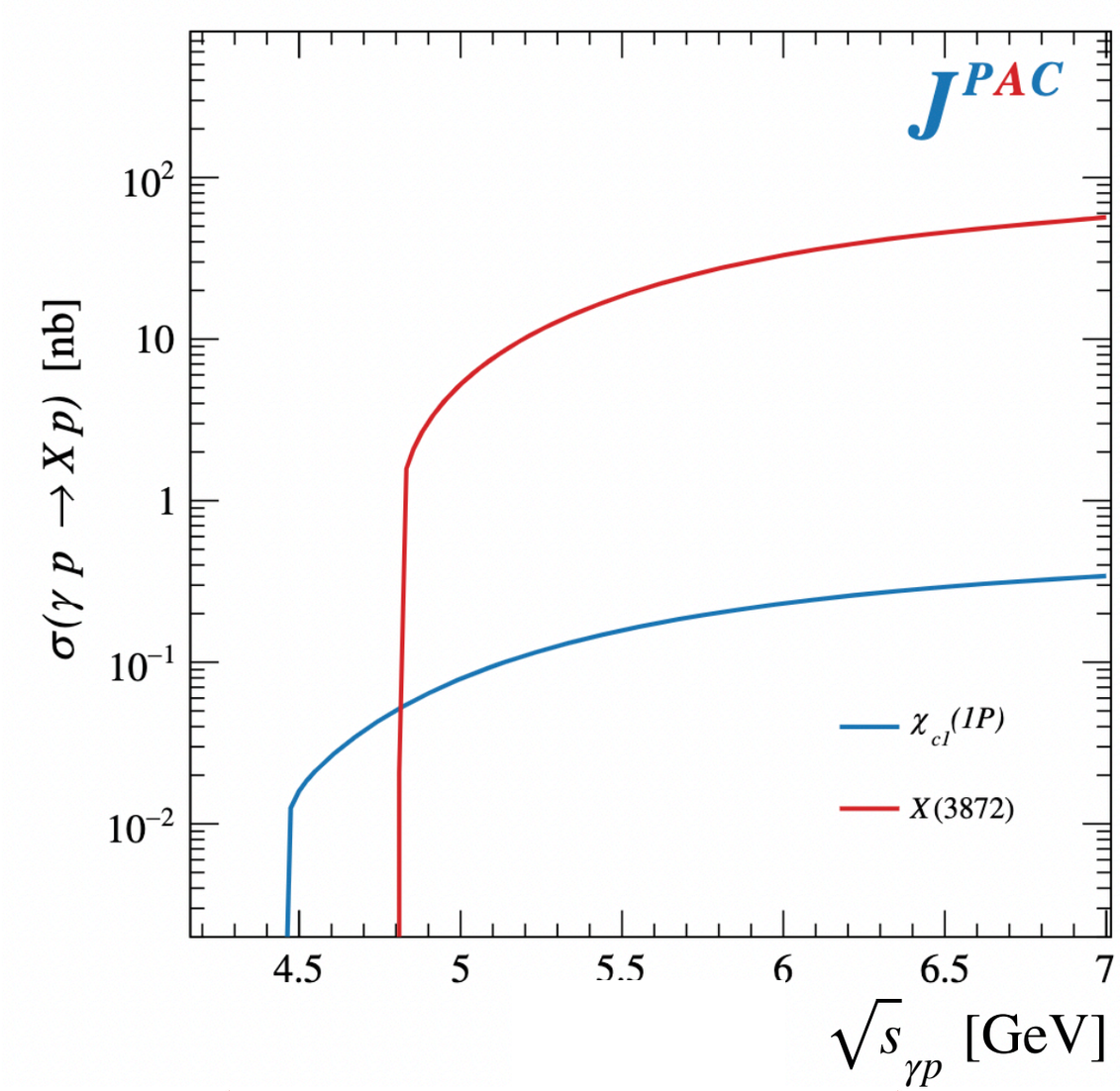
Photoproduction of $X(3872)$

EIC: $\gamma p \to pJ/\psi\pi^+\pi^-$



JLab 22 GeV: $\gamma p \to pJ/\psi\pi^+\pi^-$

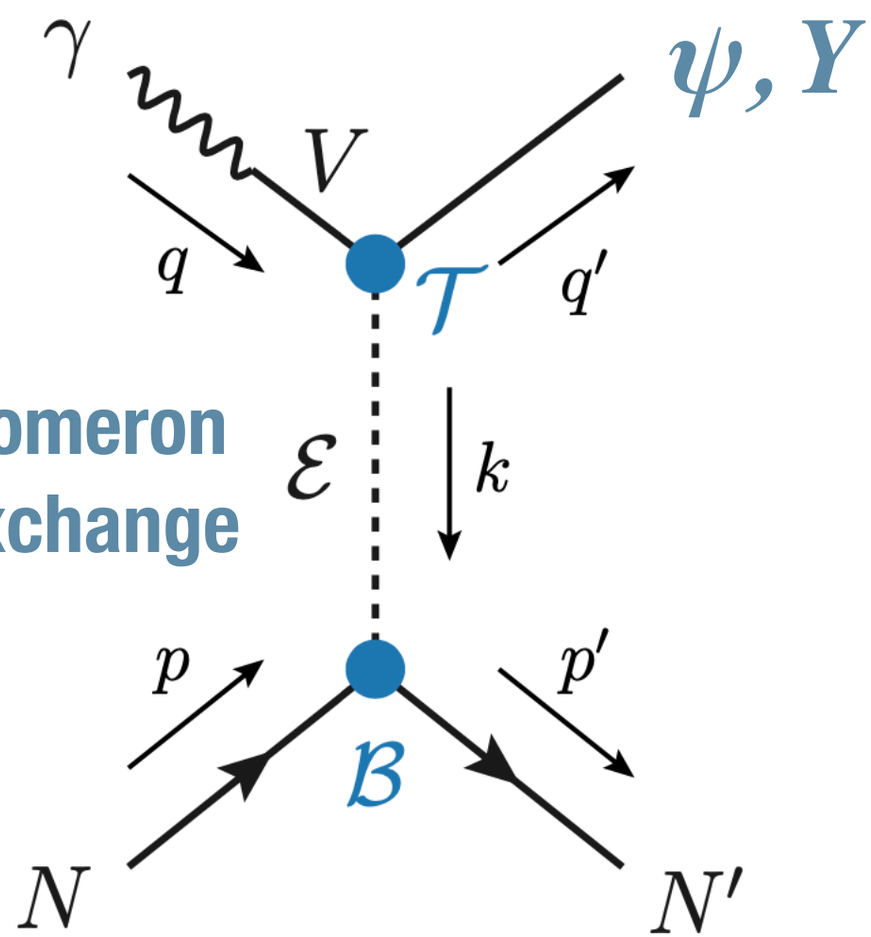




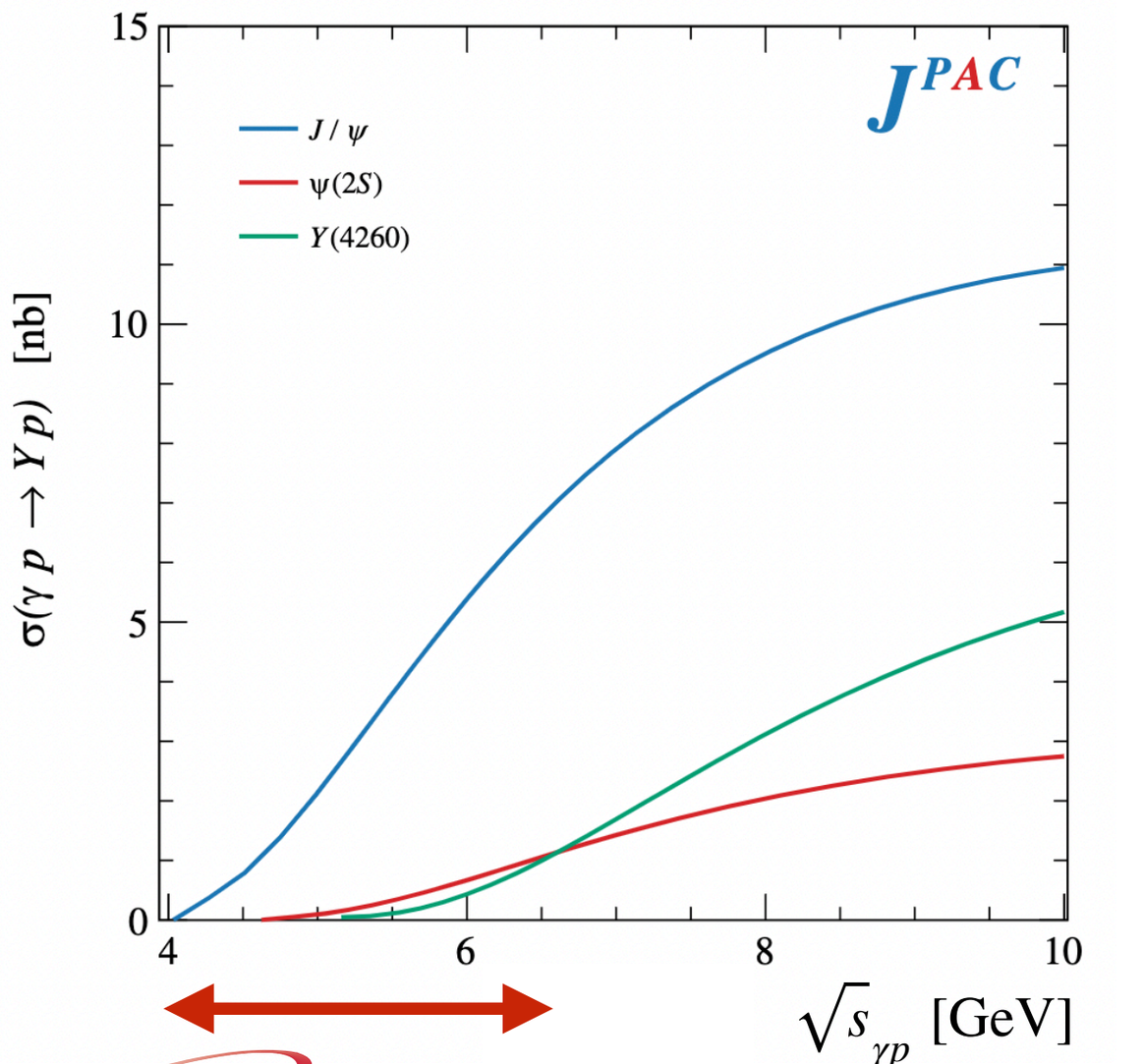
Jefferson Lab 22 GeV

Photoproduction of XYZ states

JPAC: PRD 102, 114010 (2020)



EIC

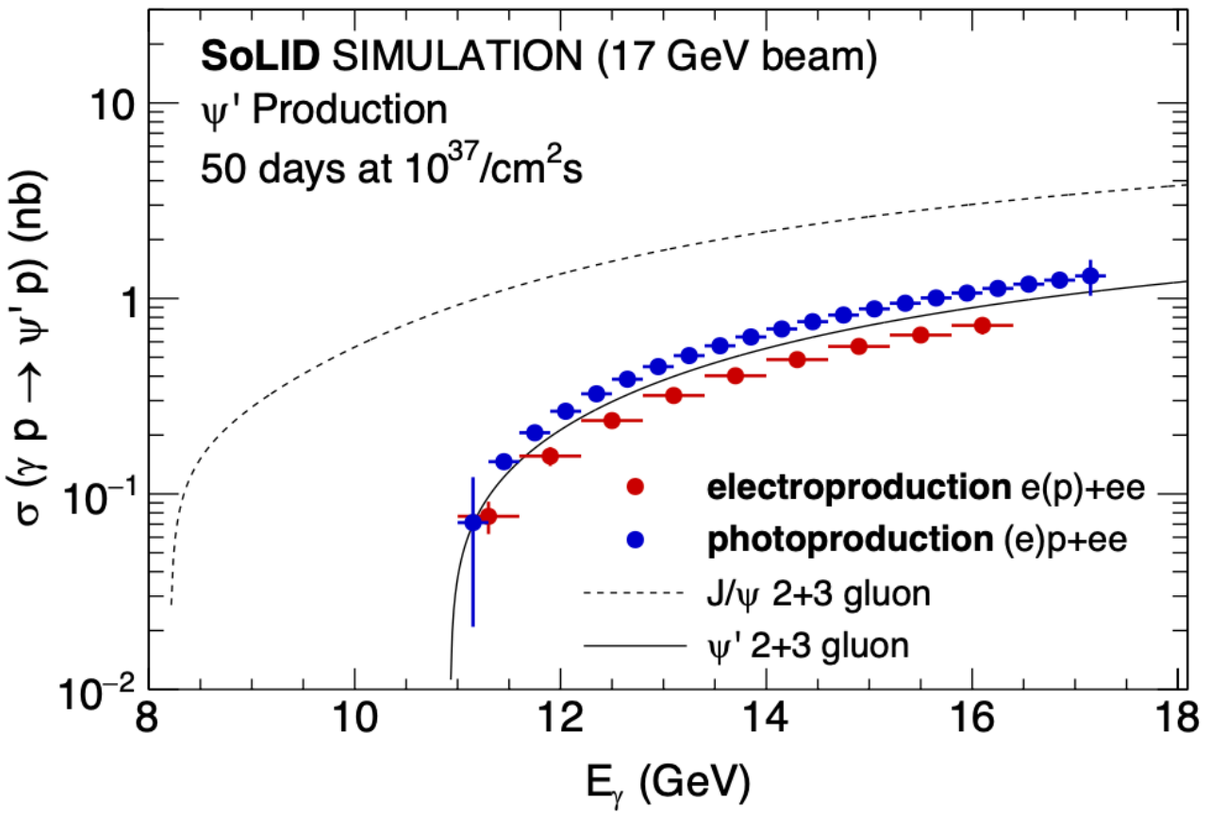


Jefferson Lab 22 GeV

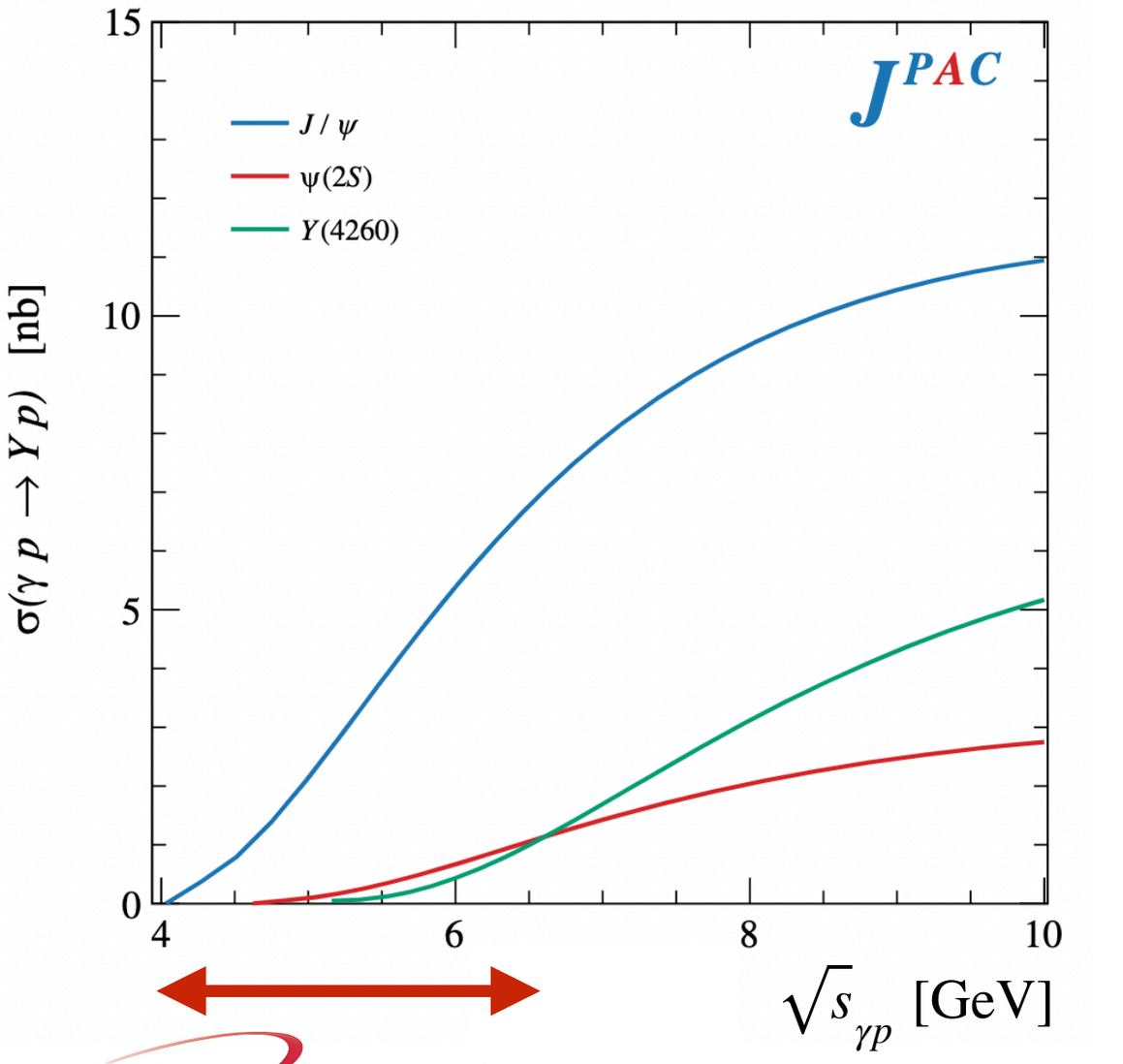
Y(4260) production increases with energy like other vectors, ideal for higher energies accessible at EIC

Photoproduction of $\psi(2S)$

SoLID example at 17 GeV



EIC



JLab 22 GeV ideal to study threshold $\psi(2S)$ production, but limited access to Y(4260) region

Jefferson Lab 22 GeV