Measuring the X(Y)Z at JLab22

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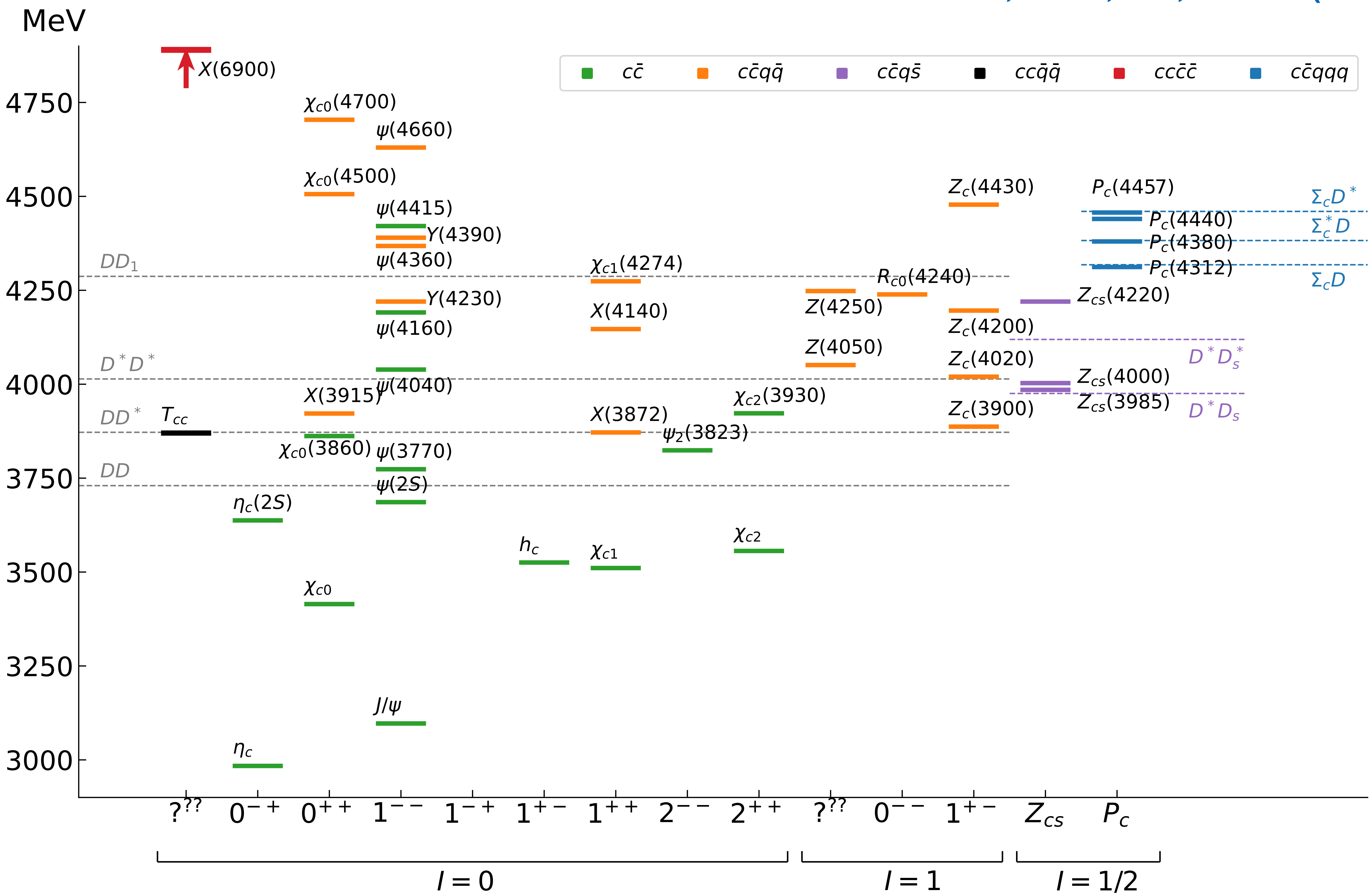
22 GeV Open Discussion
Sept. 23, 2024

Jefferson Lab

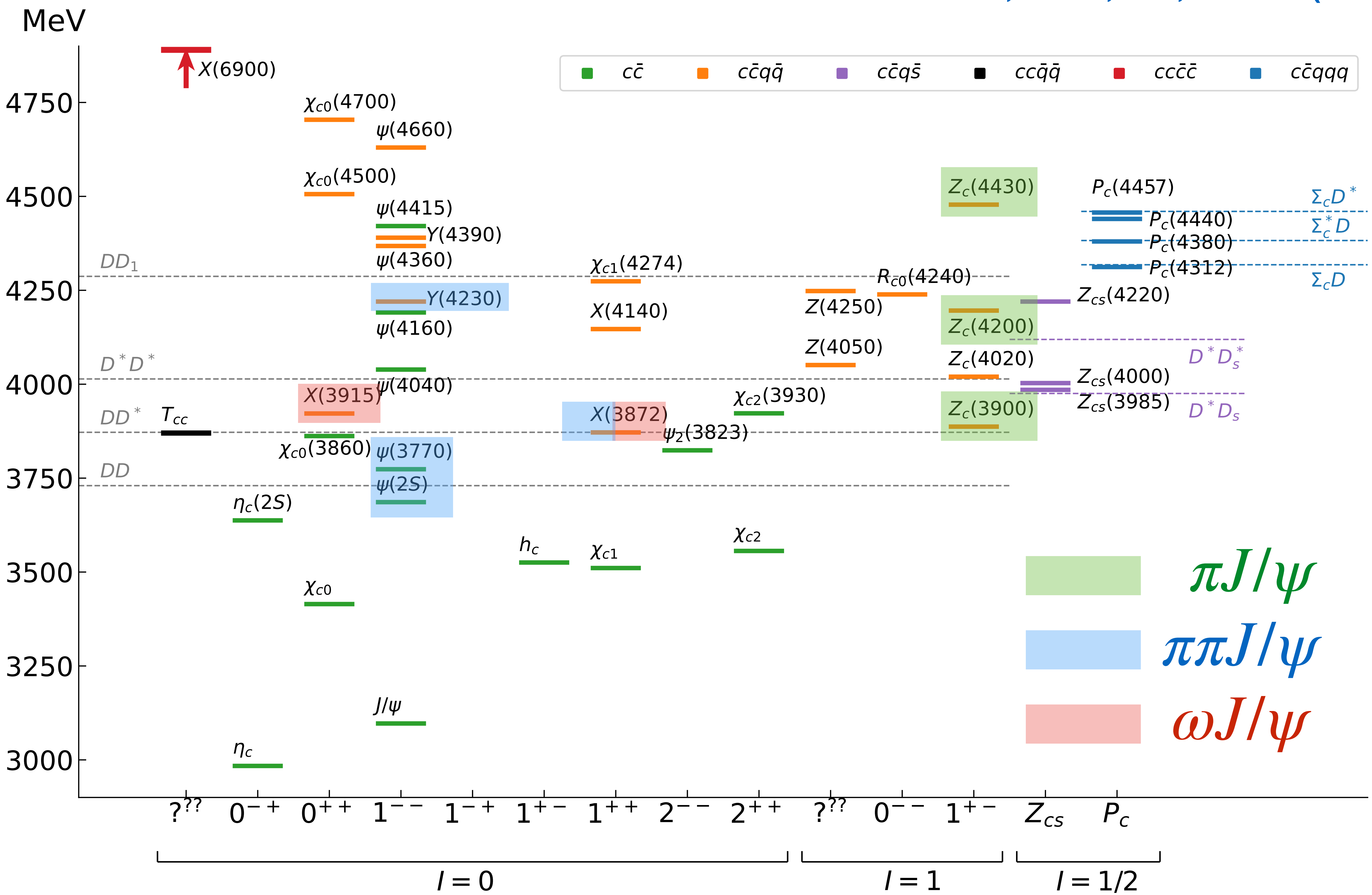
FSU

JPAC, PPNP, 127, 103981 (2022)



- Photoproduction can confirm non-$q\bar{q}$ candidate states
- "clean" theoretical framework, and free from rescattering mechanisms

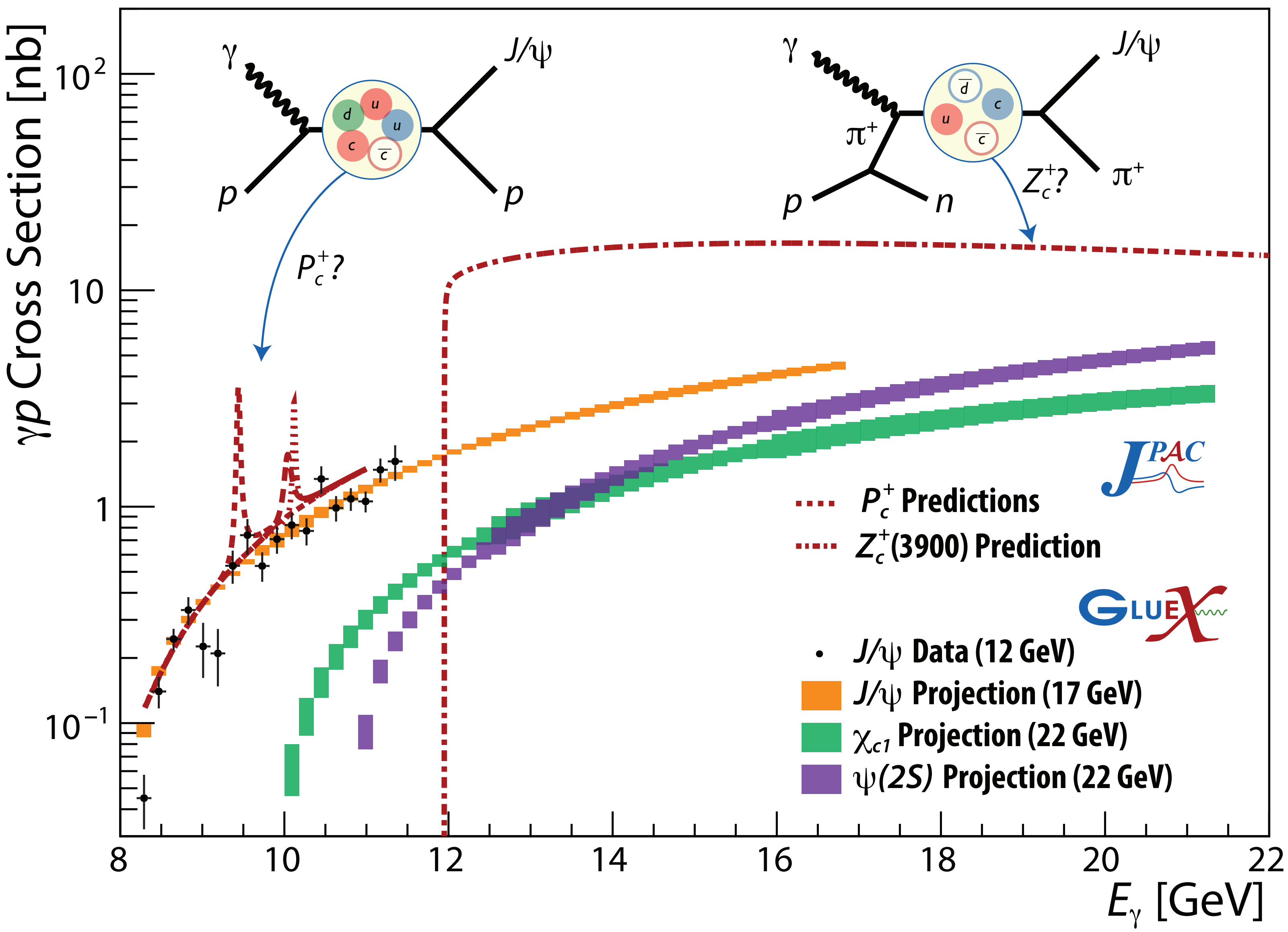
JPAC, PPNP, 127, 103981 (2022)



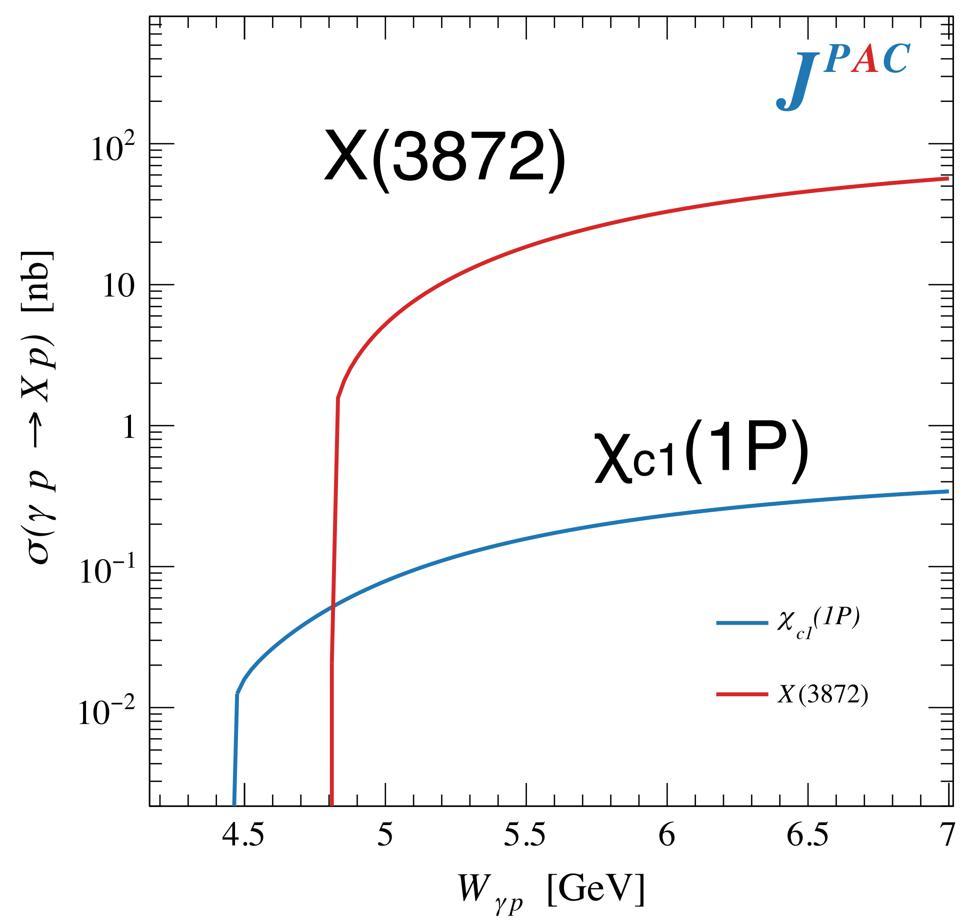
- Start looking at “discovery modes”: $\pi J/\psi$, $\pi\pi J/\psi$
- Well matched for large acceptance detectors in Halls B and D

JPAC Cross Section Predictions

EPJA 60, 9 (2024)

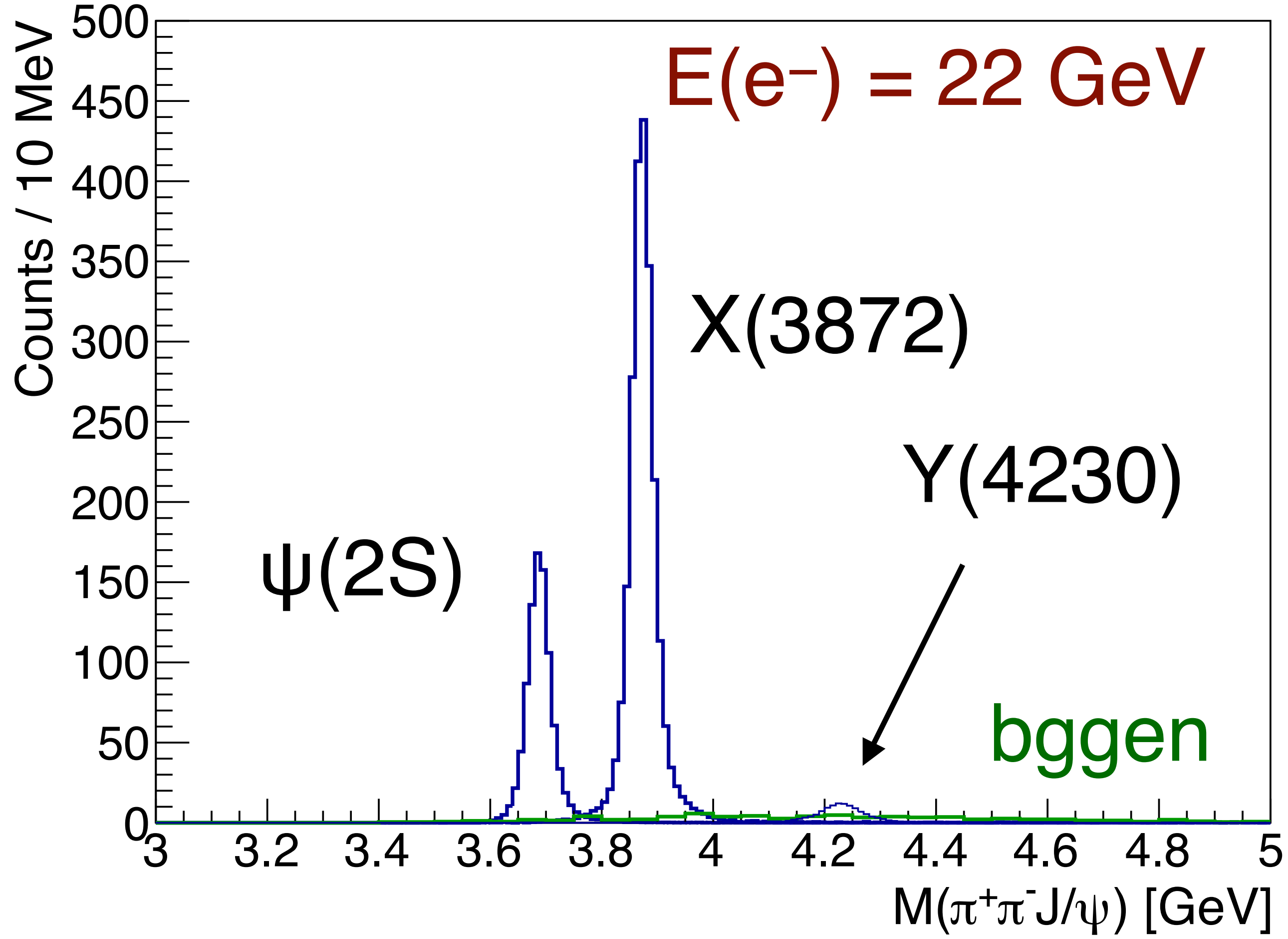


JPAC, PRD 102, 114010 (2020)



Projections for J/ψ$\pi^+\pi^-$ Photoproduction at GlueX

γp → J/ψ$\pi^+\pi^-$p, J/ψ → e^+e^-

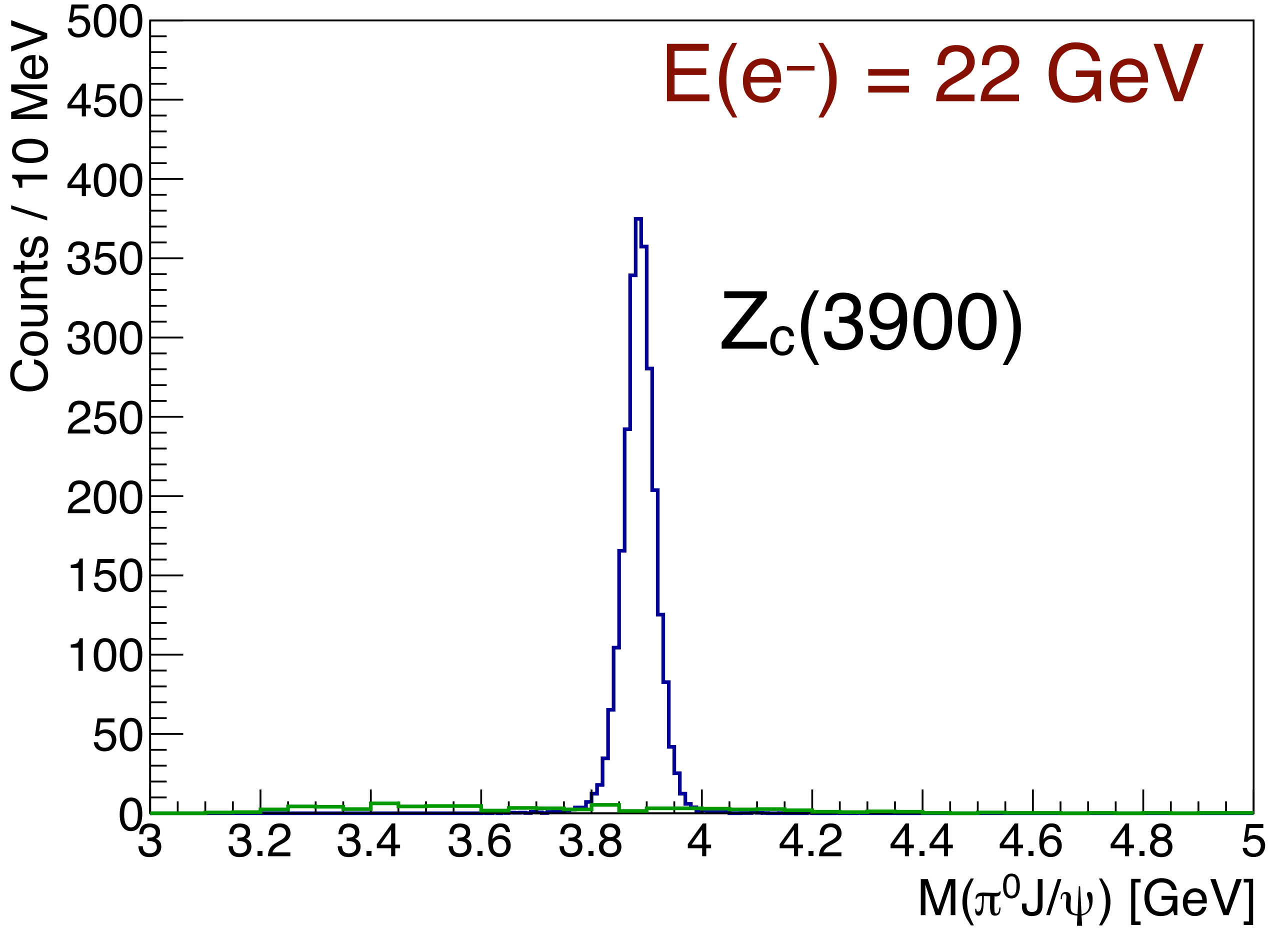


fully reconstructed events

- Performed simulations with nominal GlueX-II configuration
  - GlueX-III plans for twice GlueX-II luminosity
- Assumes 1 year @ 500 pb^{-1}, Br(X,Y→ $\pi^+\pi^-$J/ψ) = 5%
- Efficiencies around 10% (n.b. excl. J/ψ eff. around 20%)
- 22 GeV e^-: N(ψ(2S)) = 900, N(X(3872)) = 2300, N(Y(4260)) = 120

Projections for $J/\psi\pi$ Photoproduction at GlueX

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



- Assumes 1 year @ 500 pb^{-1}, $Br(Z_c \to \pi J/\psi) = 5\%$
  - $N(Z_c \to J/\psi\pi) \approx 2500$ from $\gamma p \to Z_c^- \Delta^{++}$
- Can compare charged and neutral Z_c production
  - Neutral production cross sections more uncertain

CLAS24 Simulations

Courtesy of D. Glazier

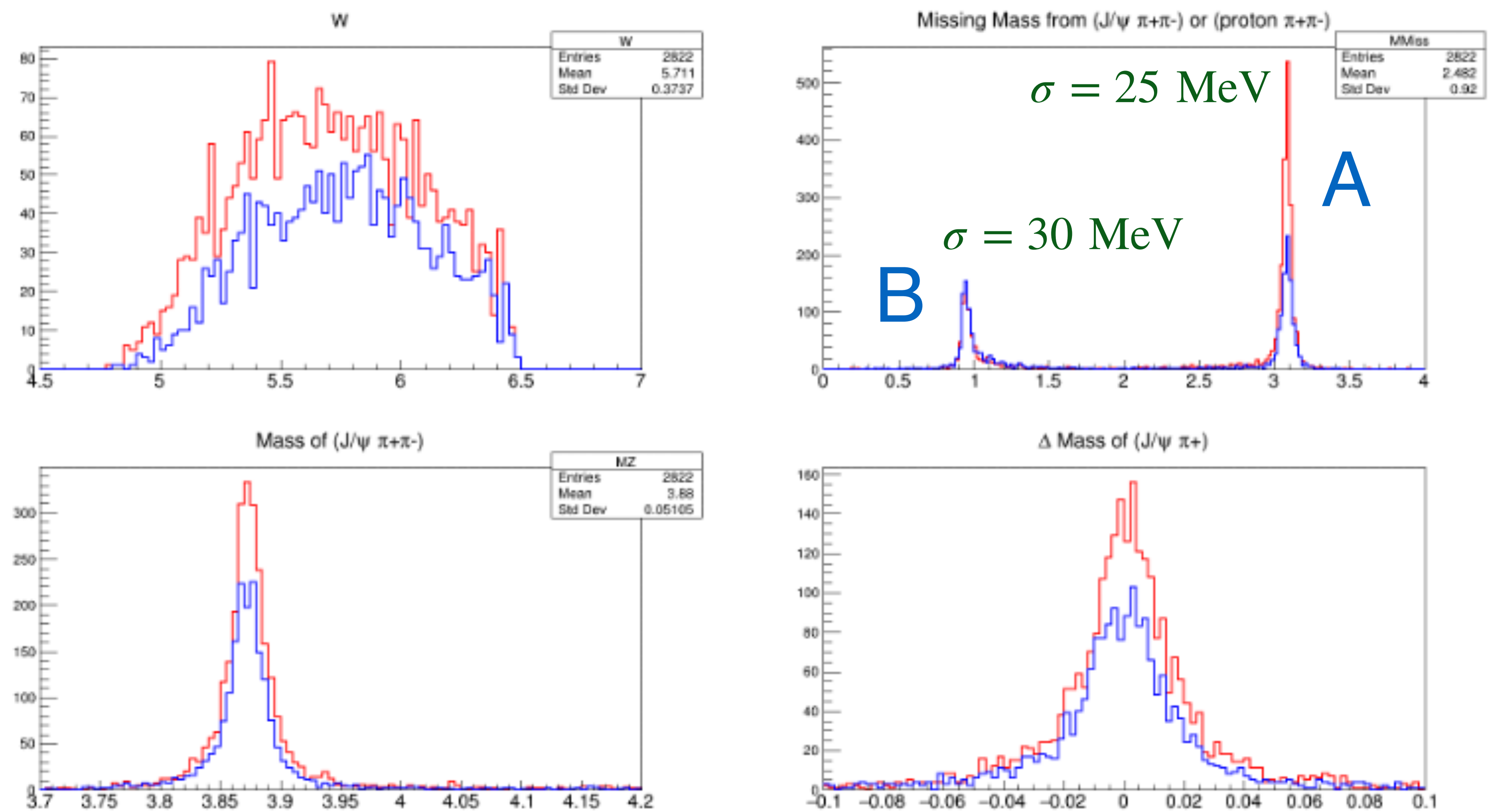
- CLAS12 has excellent PID
- Can measuring missing particles
- Simulations assuming $10^{35}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ luminosity for 50 days, zero-degree tagger

$$X(3872) \rightarrow \pi^+\pi^- J/\psi$$

A) Missing J/ψ B) Missing proton

Acceptances:
X(3872) ≈ 1%
Z_c(3900) ≈ 15%

Expected yields:
X(3872) = 2-3k
Z_c(3900) = 25k

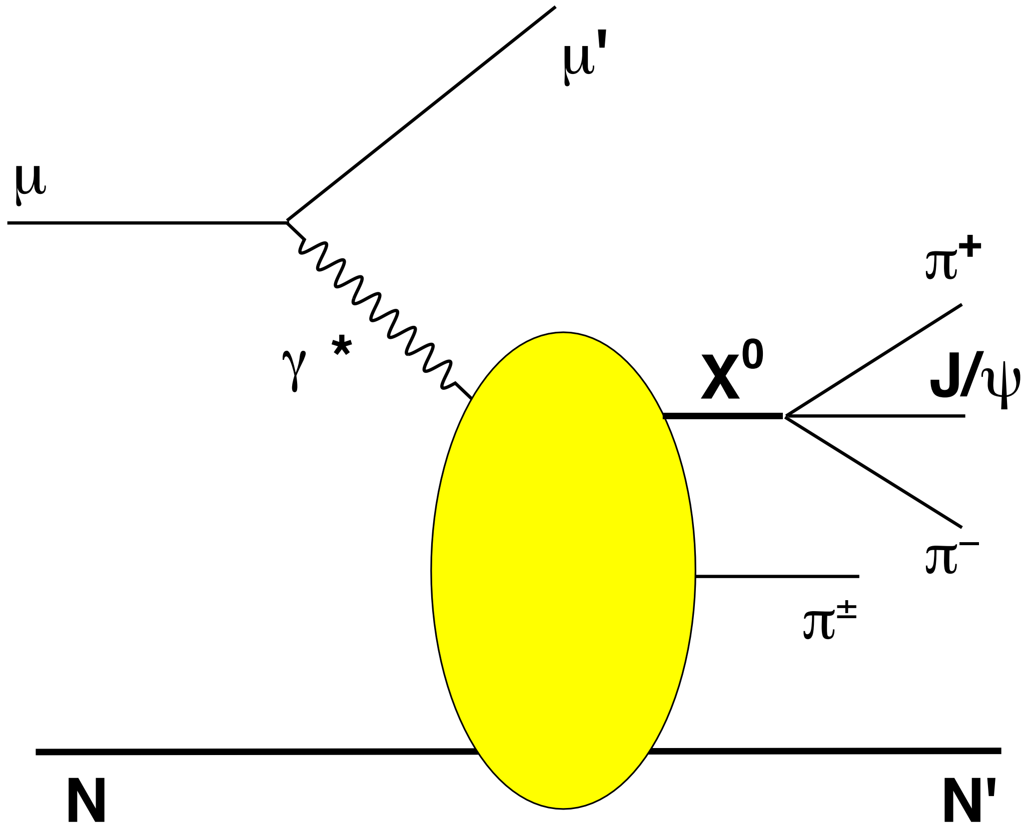


COMPASS measurements of $\pi^+\pi^- J/\psi$

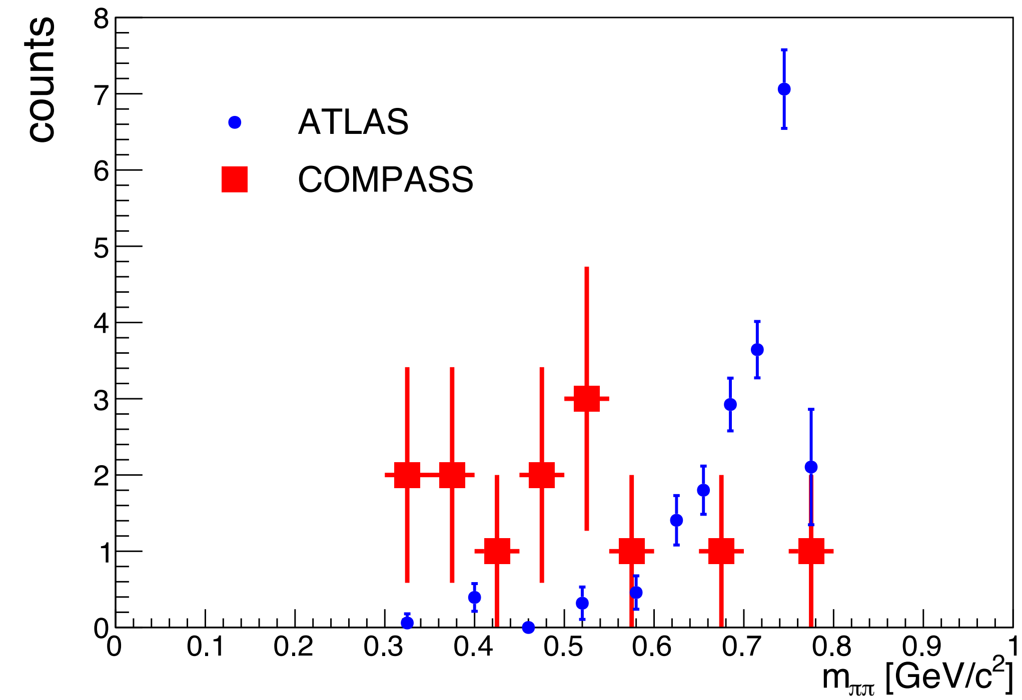
- Can we estimate backgrounds from other measurements?

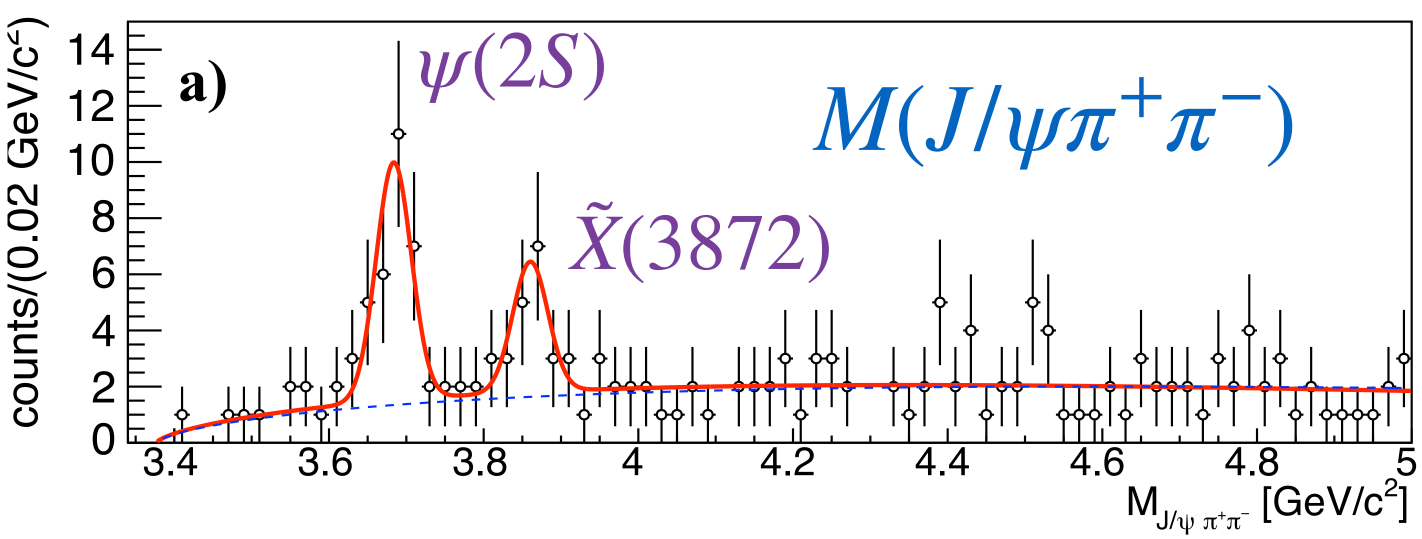
$$\mu^+ N \rightarrow \mu^+ (J/\psi \pi^+ \pi^-) \pi^\pm N'$$

160/200 GeV/c μ^+ on ^{6}LiD or NH_3



$M(\pi^+\pi^-)$





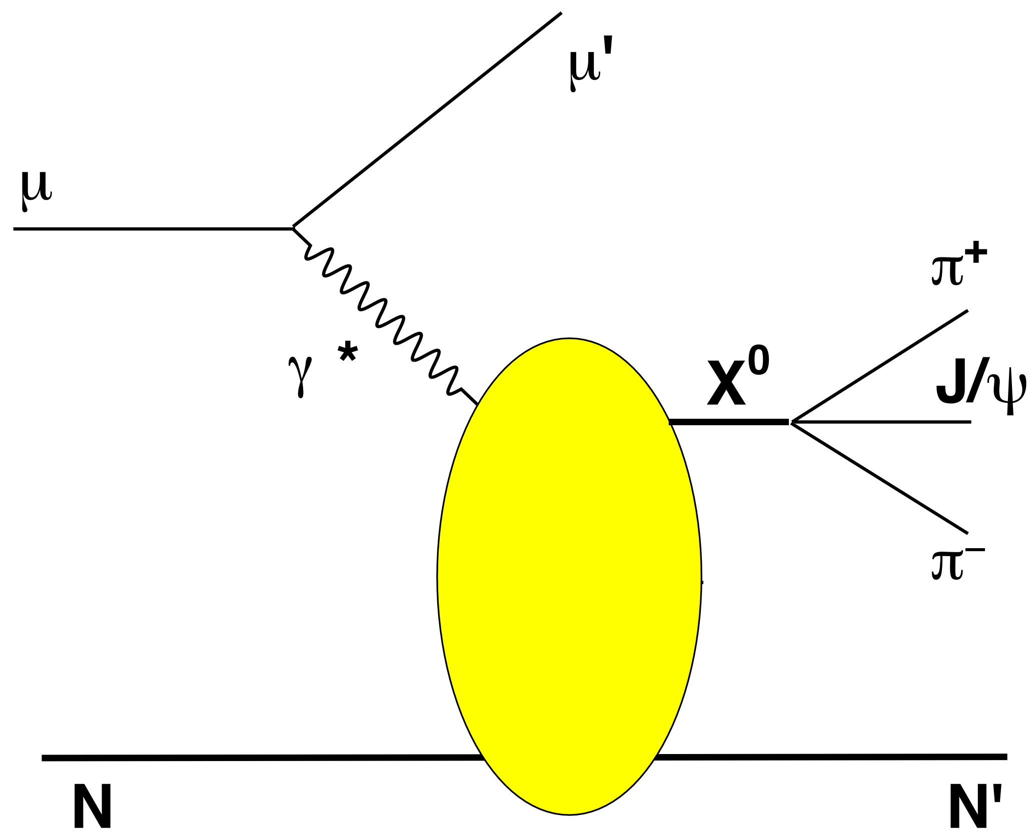
COMPASS, PLB 783, 334 (2018)

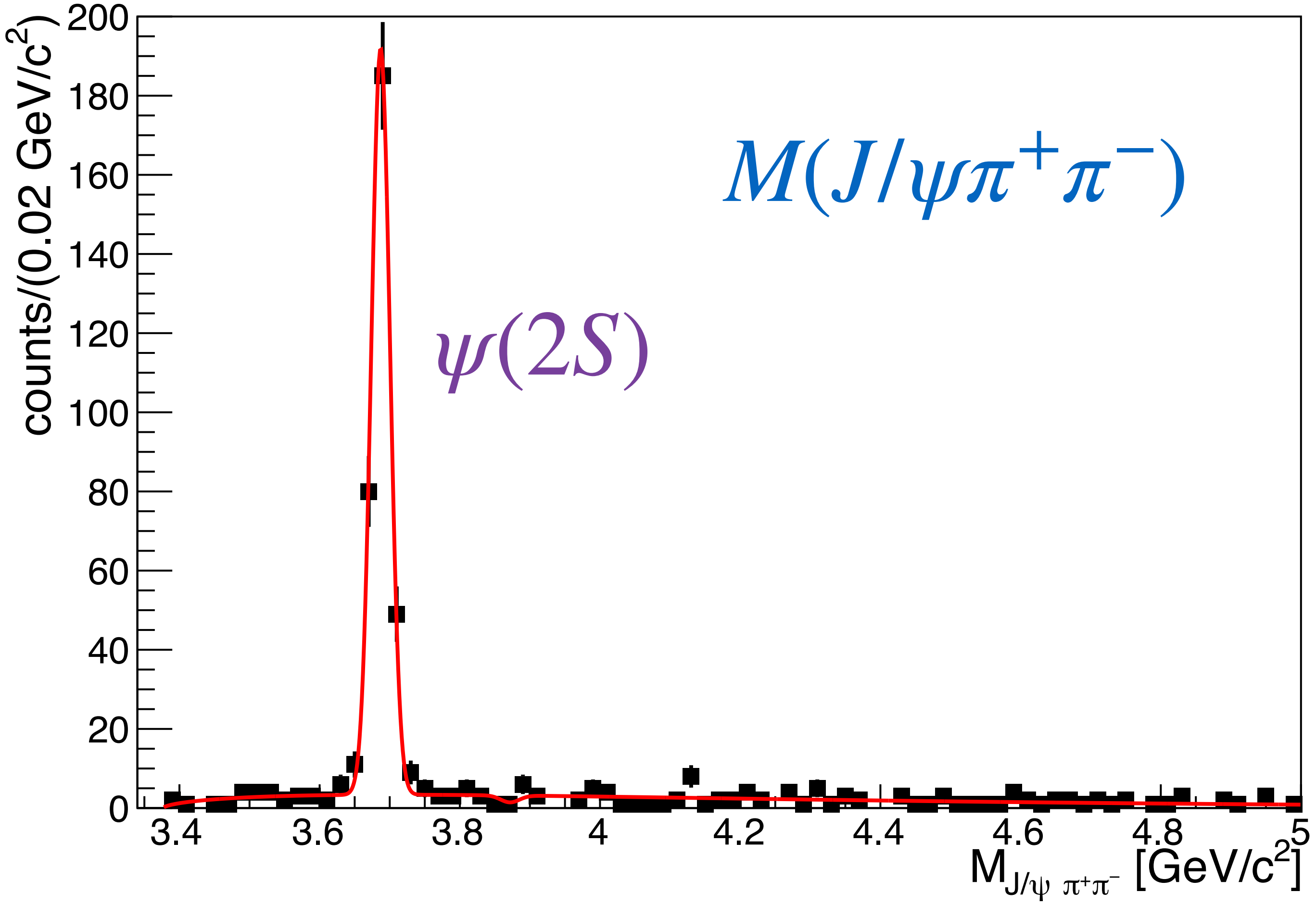
COMPASS measurements of $\pi^+\pi^- J/\psi$

- Can we estimate backgrounds from other measurements?

$$\mu^+ N \to \mu^+ (J/\psi \pi^+ \pi^-) \pi^\pm N'$$

160/200 GeV/c μ^+ on ^{6}LiD or NH_3 $\sqrt{s_{\gamma N}} \approx 8 - 18$ GeV





COMPASS, PLB 783, 334 (2018)

Summary and Discussion

- Measuring XYZ states in photoproduction would add crucial new information to establish these states
- Measurements at JLab with 22 GeV electrons are feasible
- Some areas where more guidance could help:
  - Models to estimate backgrounds
  - What can differential cross section measurements tell us about the microscopic structure of these states?
- Points for further discussion:
  - What about establishing strange-quark partners of these states (e.g. $Z_c \to \pi J/\psi$ vs. $Z_{cs} \to KJ/\psi$)?
  - What about measuring open-charm decays?
  - What about measuring polarization observables?

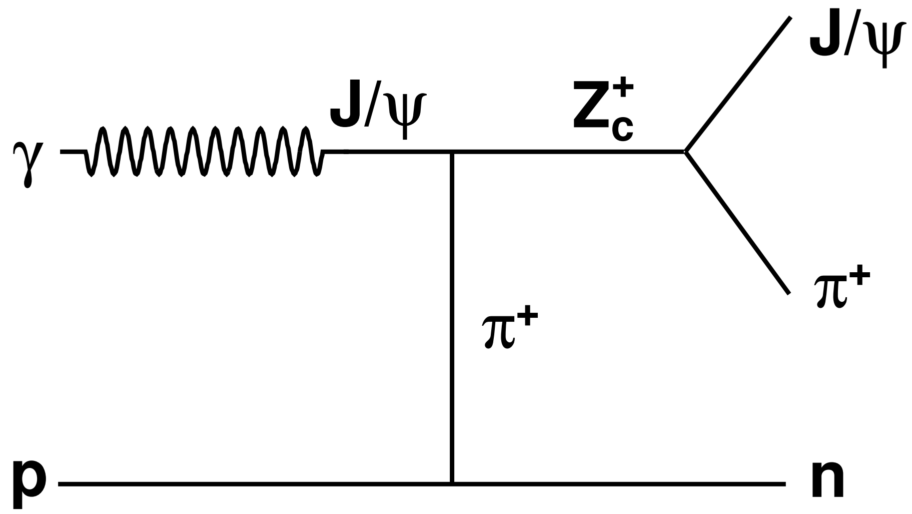
Backups

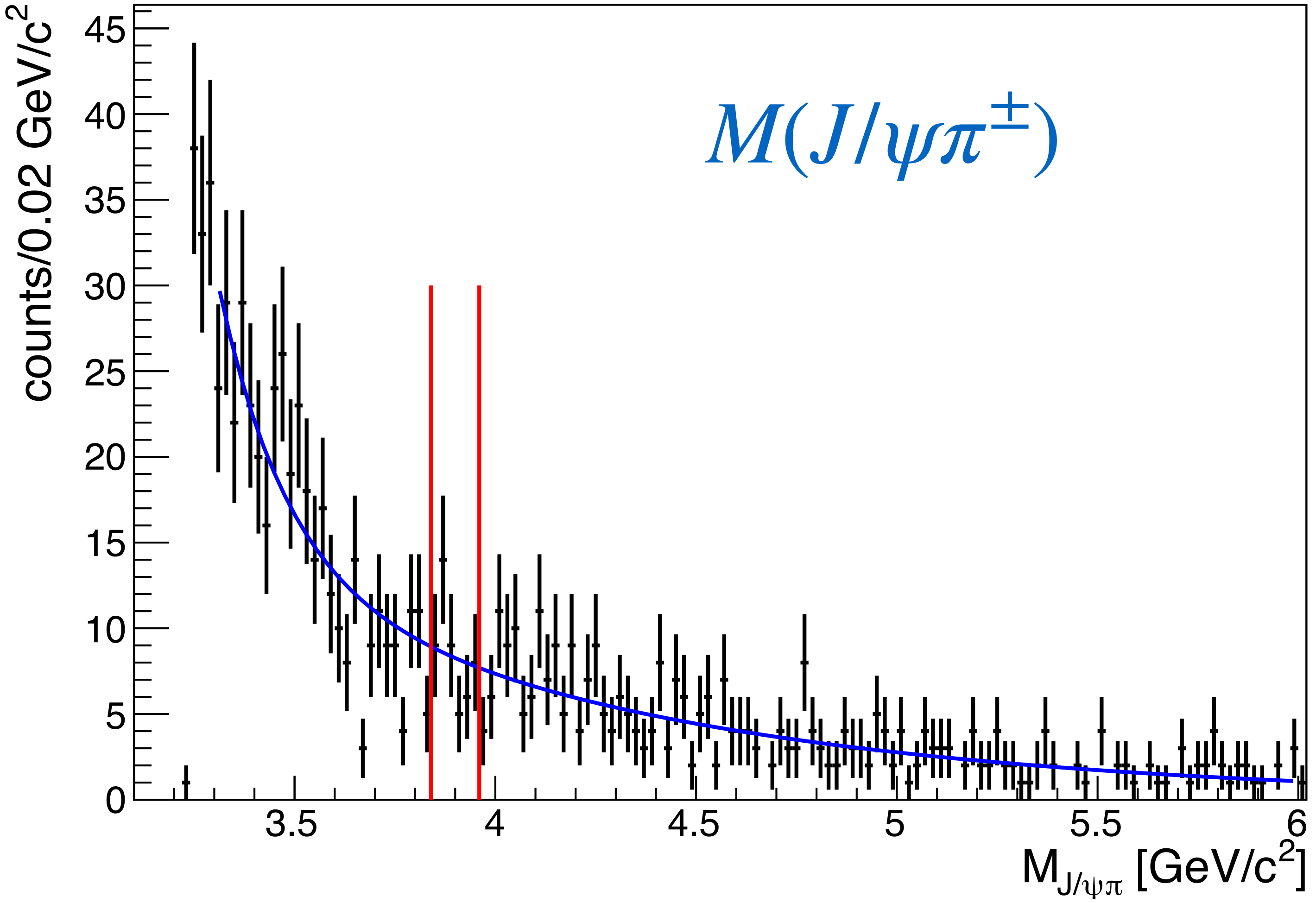
COMPASS measurements of $\pi^{\pm} J/\psi$

- Can we estimate backgrounds from other measurements?

$$\mu^+ N \to \mu^+ J/\psi \pi^{\pm} N'$$

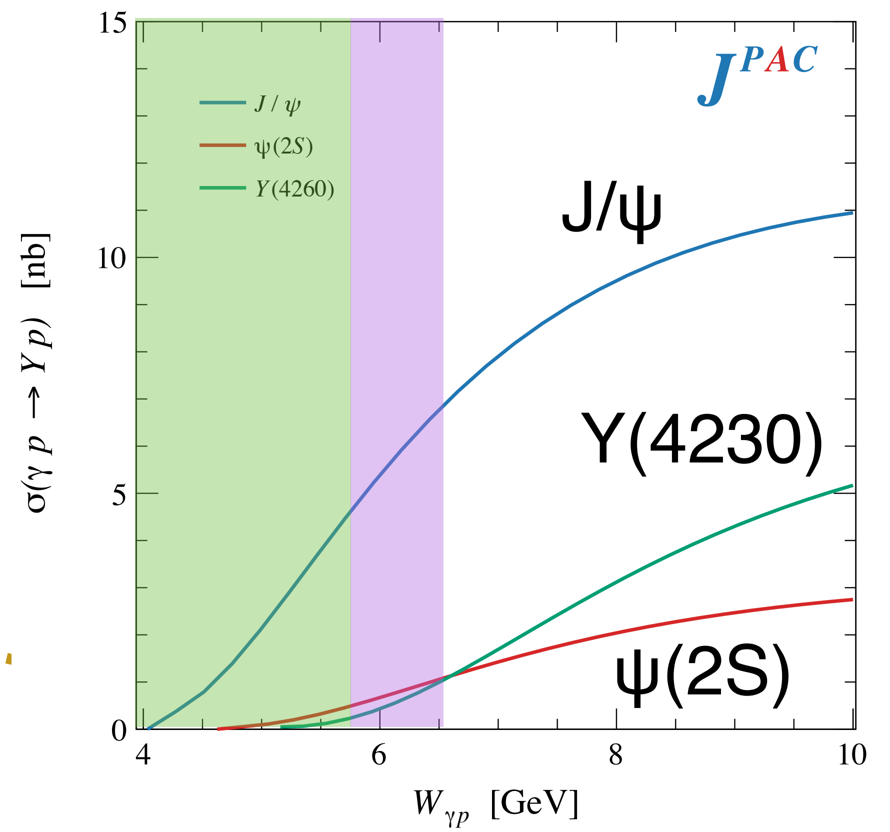
160/200 GeV/c μ^+ on ^{6}LiD or NH_3

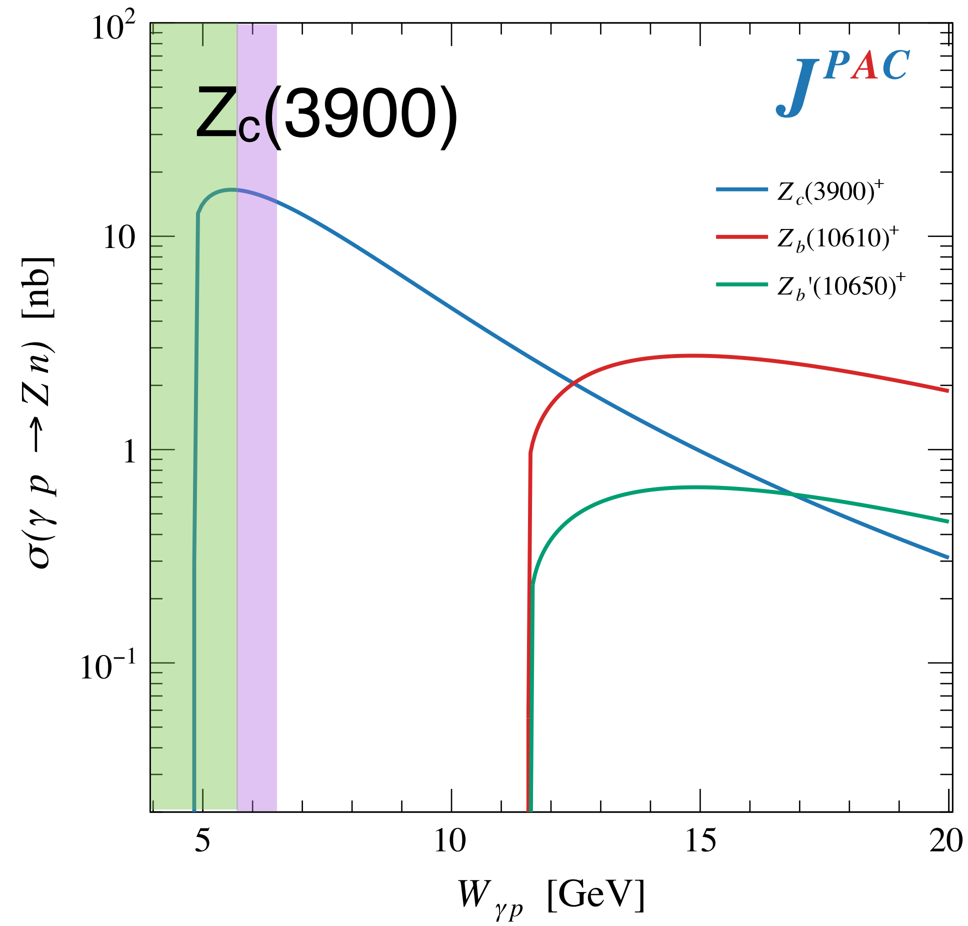


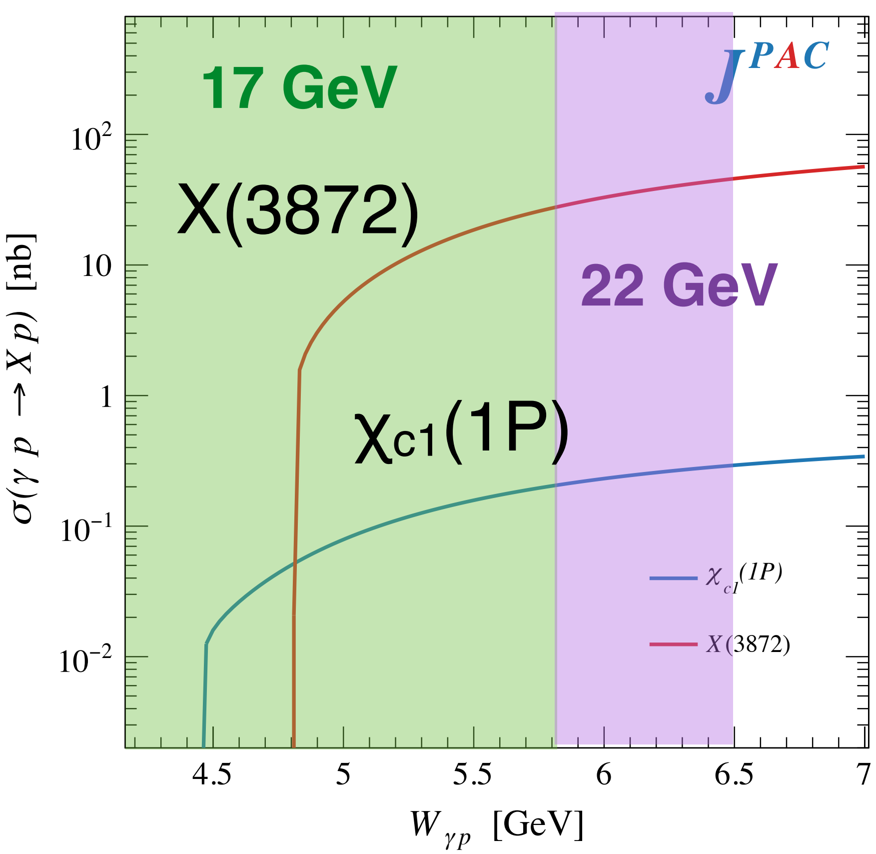


COMPASS, PLB 742, 300 (2015)

JPAC Cross Section Predictions

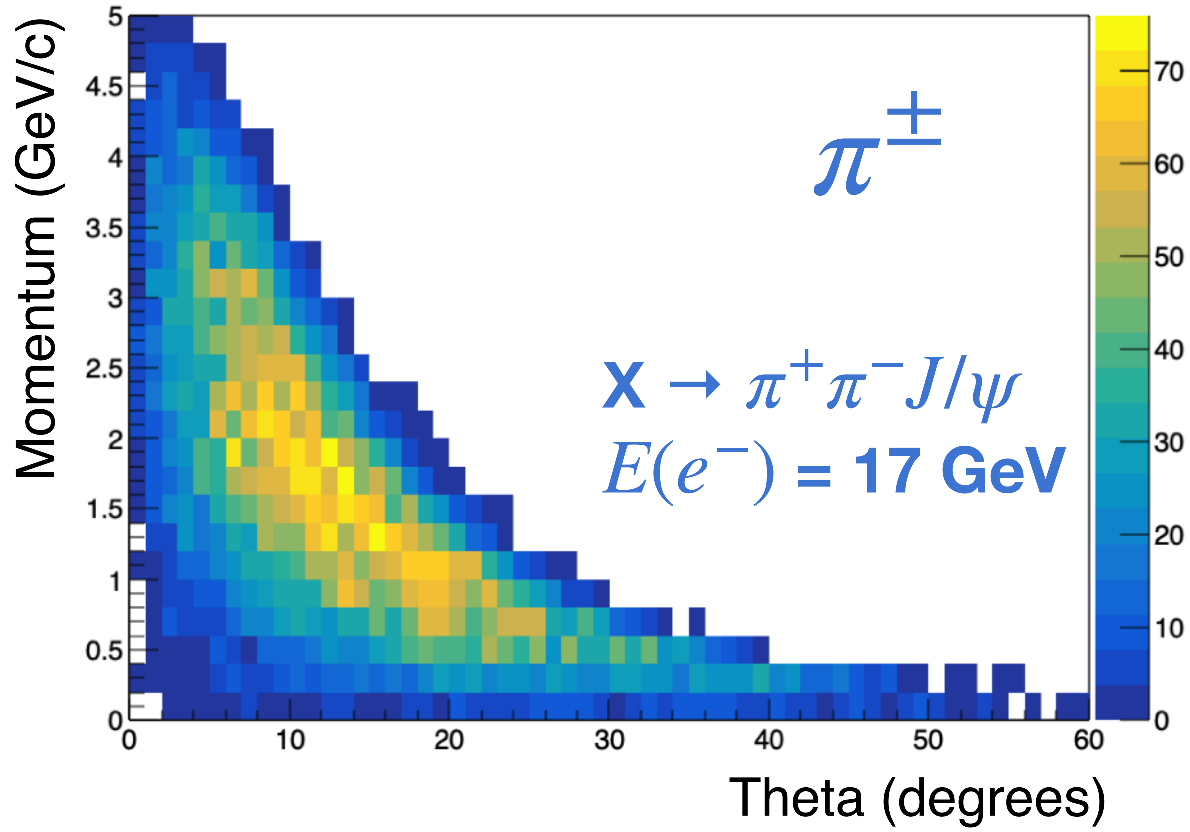


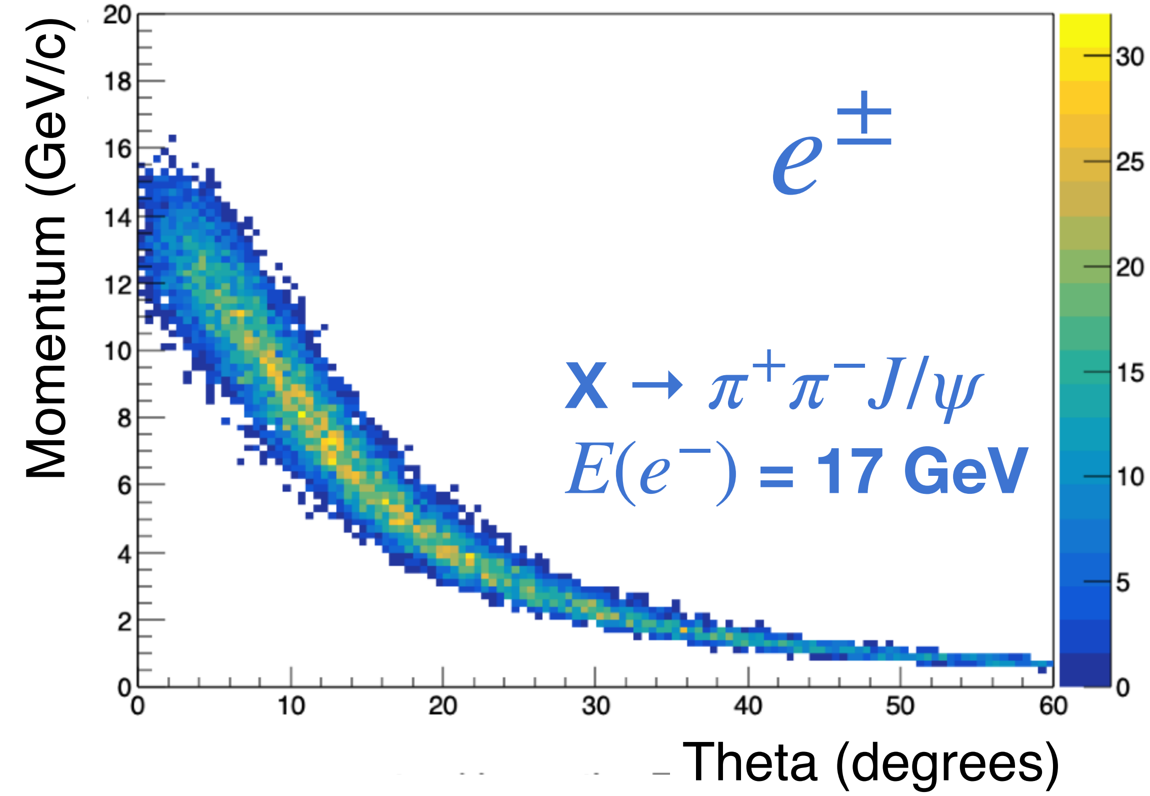




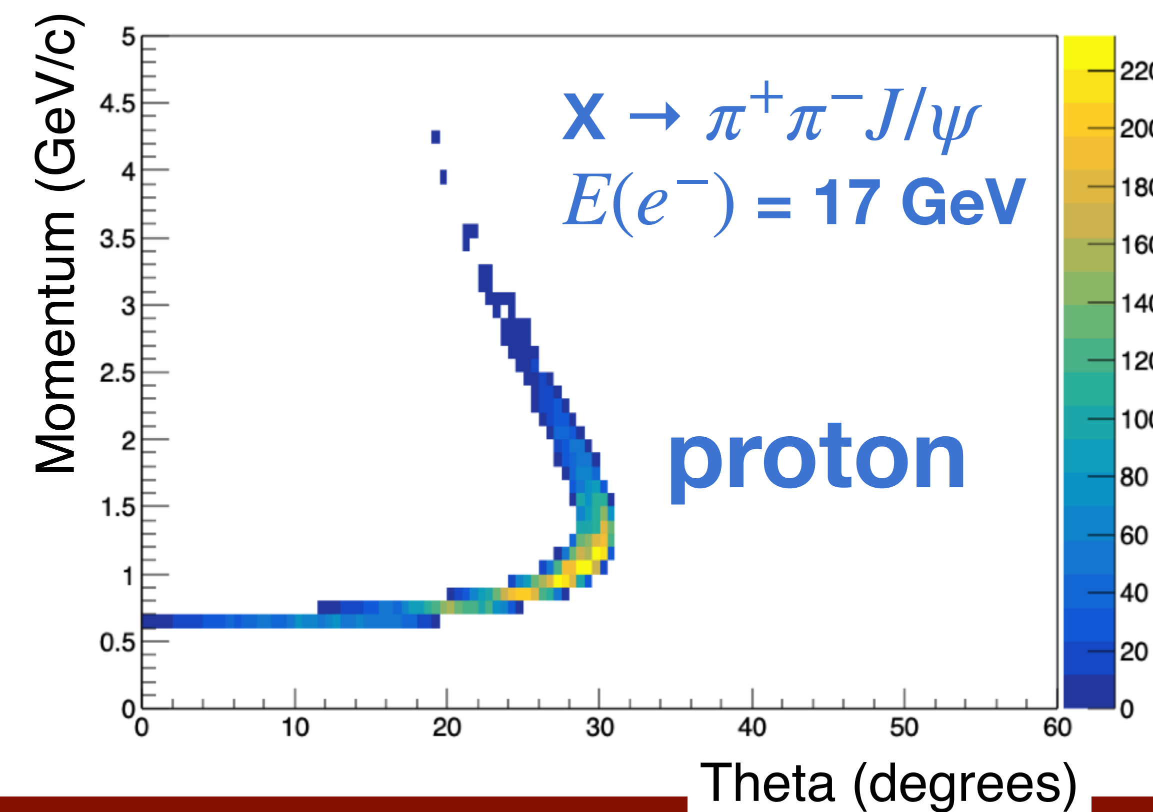
- JPAC predictions using fixed-spin exchanges near threshold
  - **PRD 102, 114010 (2020)**
- GlueX can test model by measuring $\chi_{c1}(1P)$, $\psi(2S)$ production

Kinematics of ɣp → X(3872)p, X → $\pi^+\pi^- J/\psi$



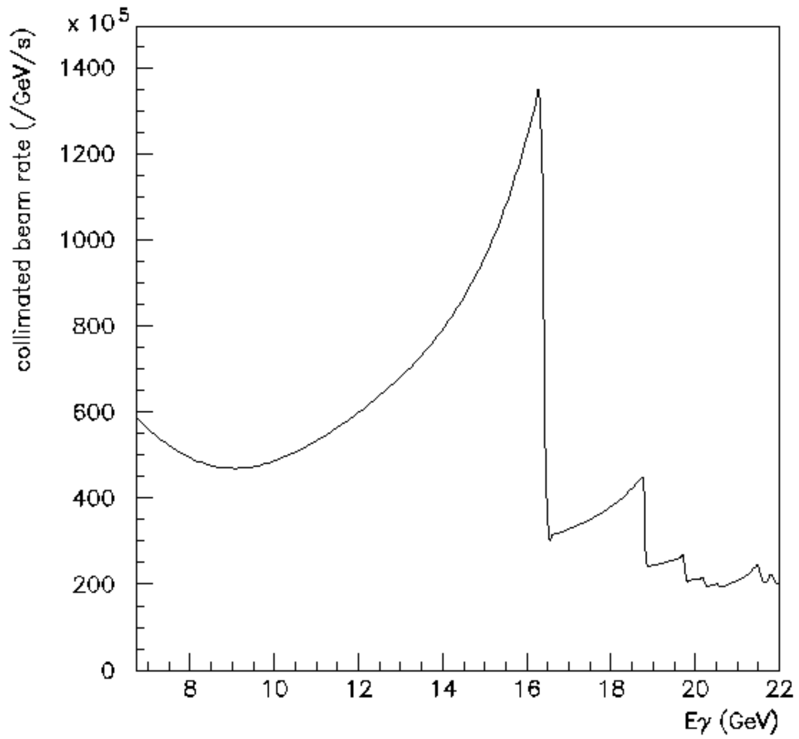


- Example: X → $\pi^+\pi^- J/\psi$ decay products are well within GlueX acceptance

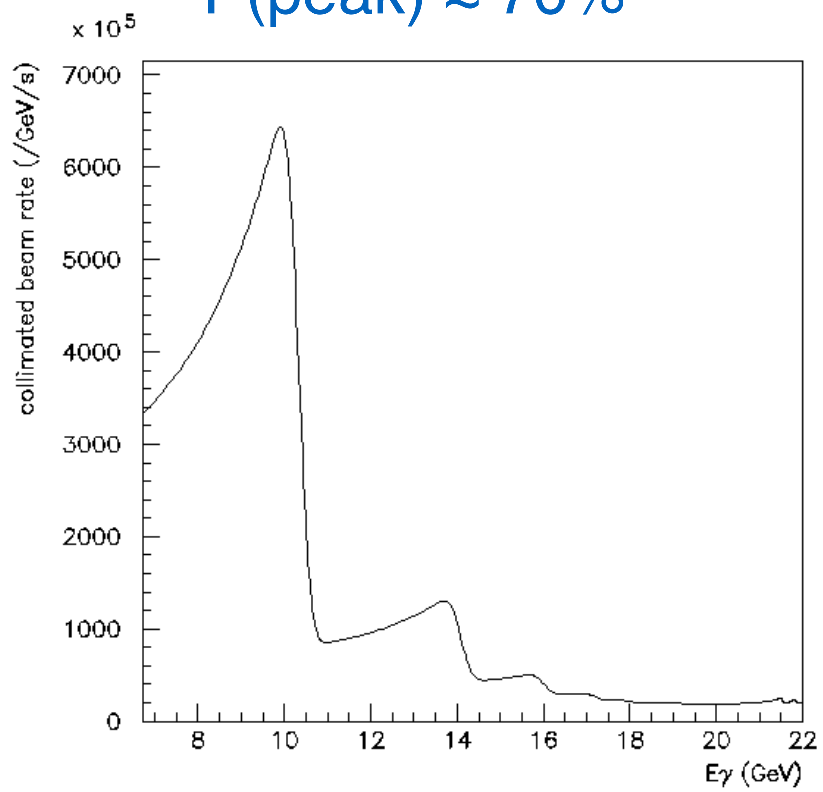


Luminosity Expectations @ GlueX

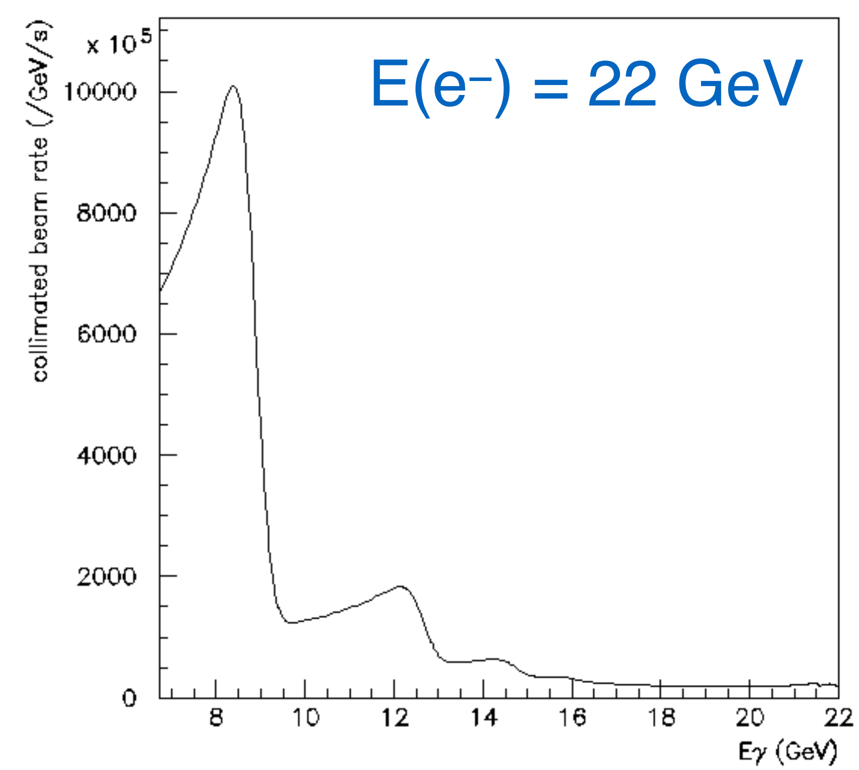
E(peak) = 16.5 GeV
P(peak) ≈ 35%



E(peak) = 10.5 GeV
P(peak) ≈ 70%

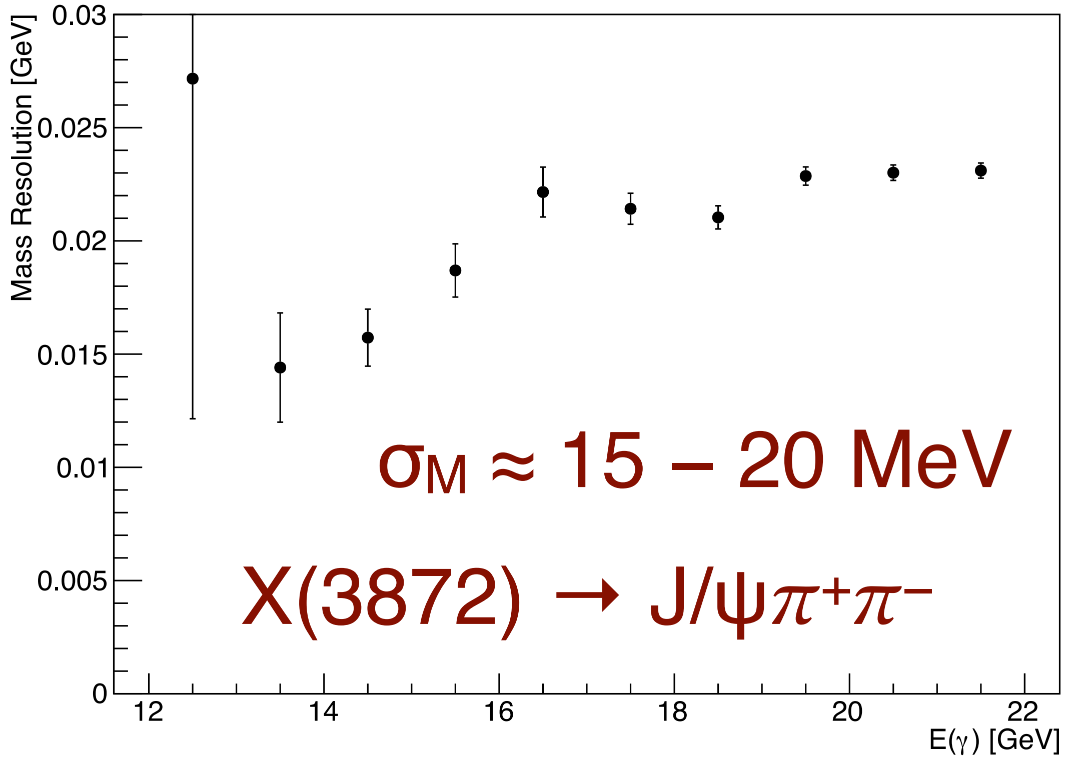


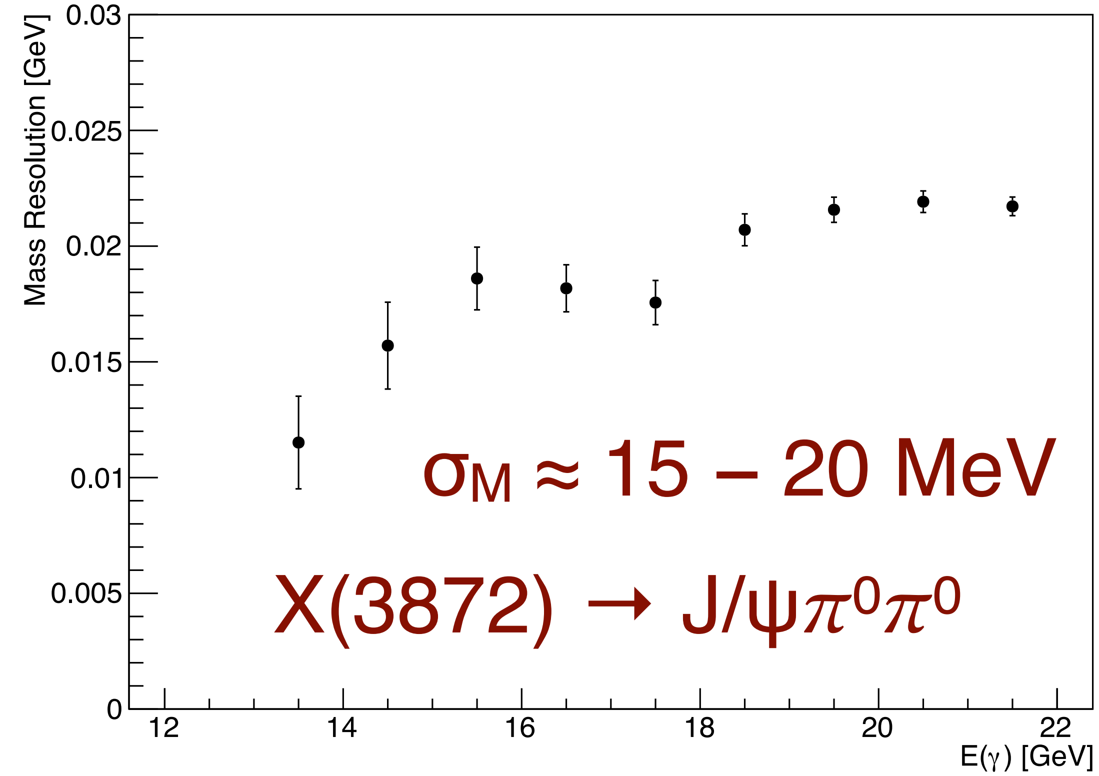
E(peak) = 9 GeV
P(peak) ≈ 80%

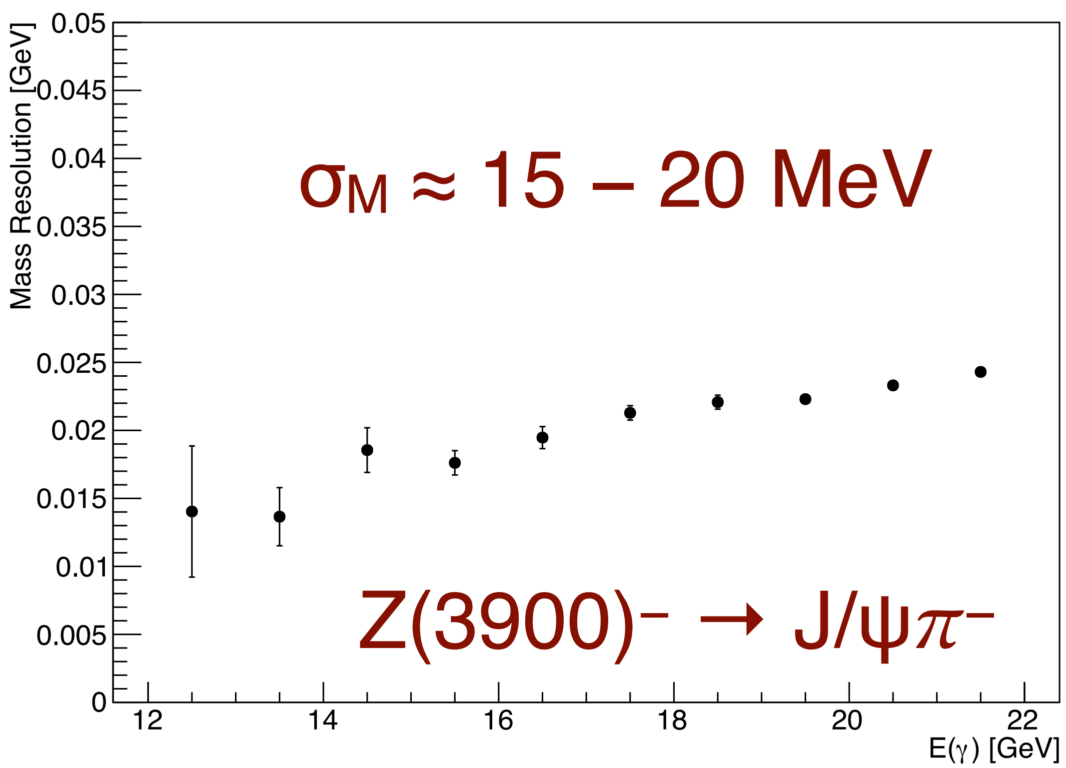


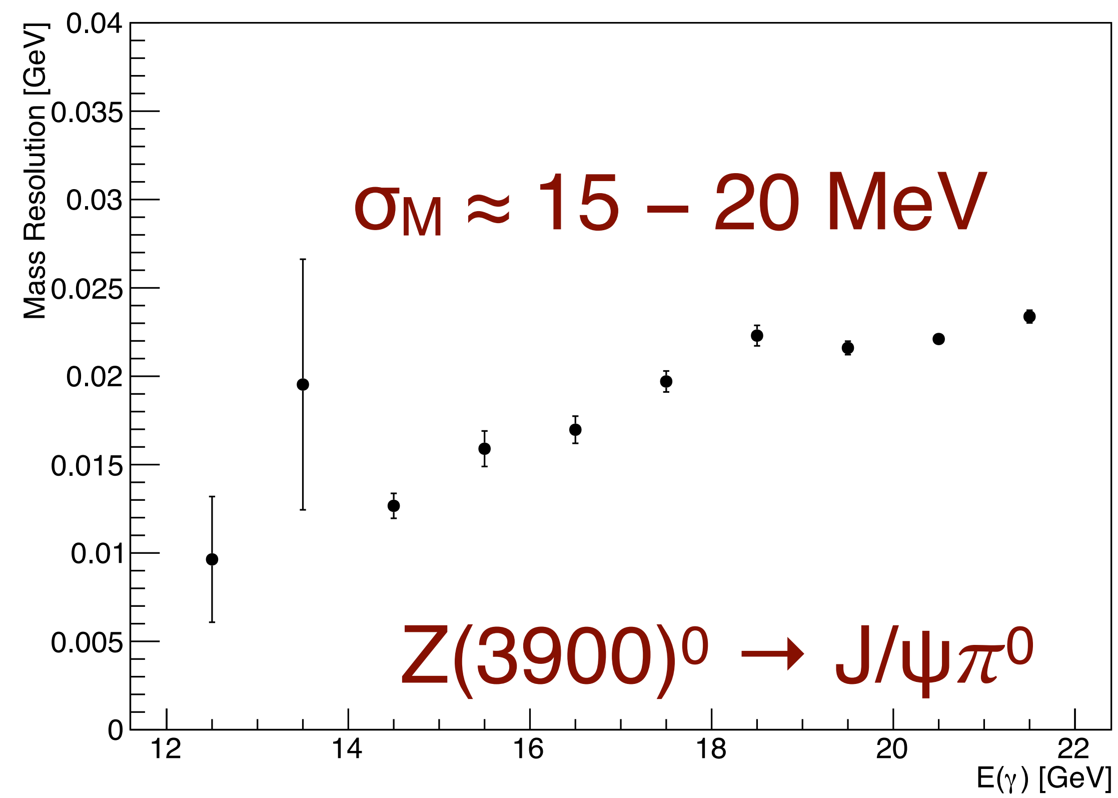
- Baseline: GlueX-II in 2020 @ 500 pb^{-1} / "year"   ($E_\gamma > E_{e-} / 2$)
  - GlueX-III approved for twice this luminosity
- This is the lower limit, ideas exist on how to go higher
  - Simple tagger upgrades → factor 4 increase
  - More restrictive trigger (think J/ψ → e+e−)
  - Rate limitations due to forward tracker / TOF ?
    → can imagine new detectors

Resolutions vs. Beam energy

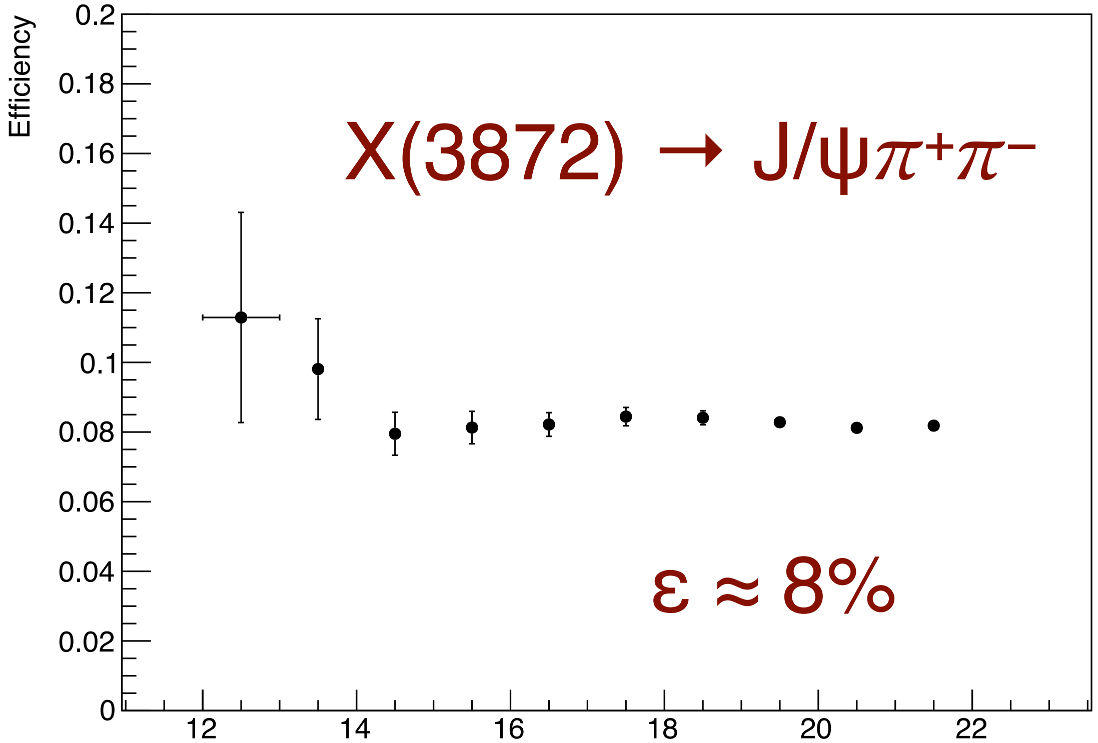


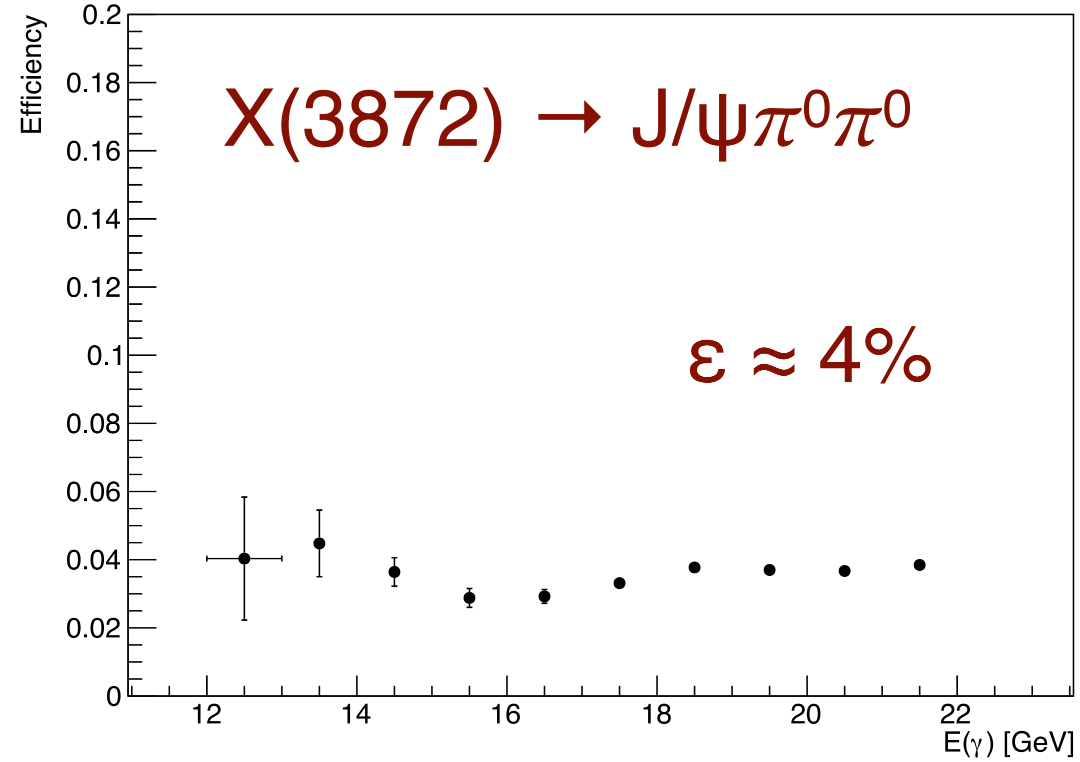


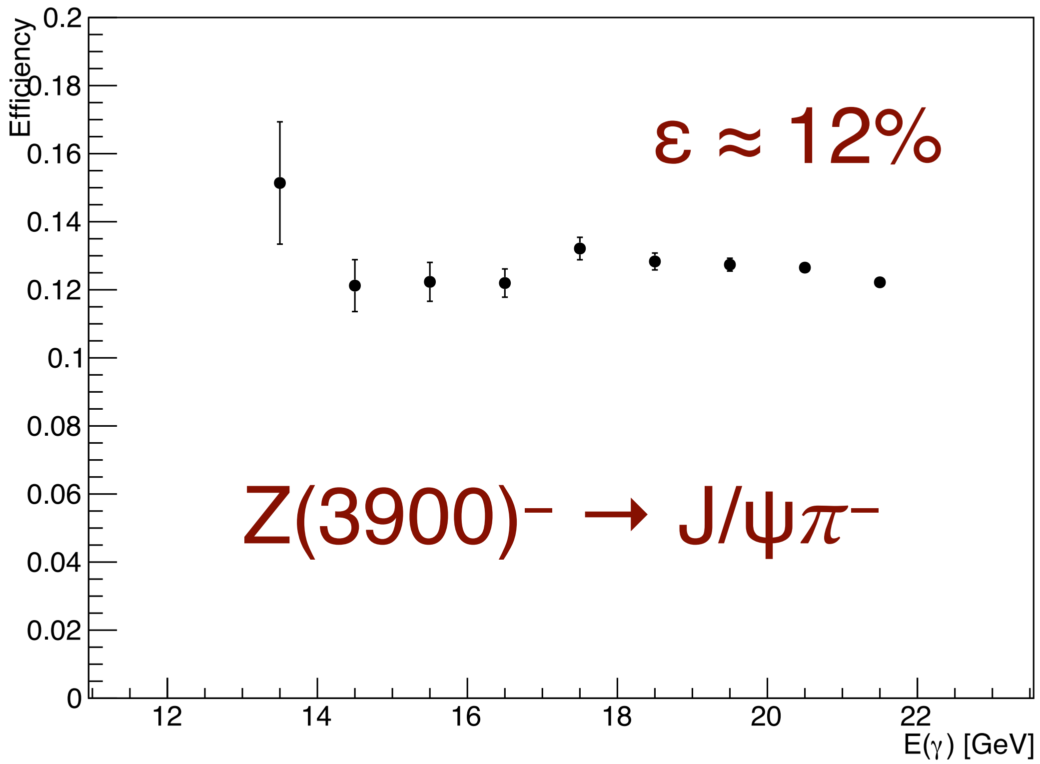


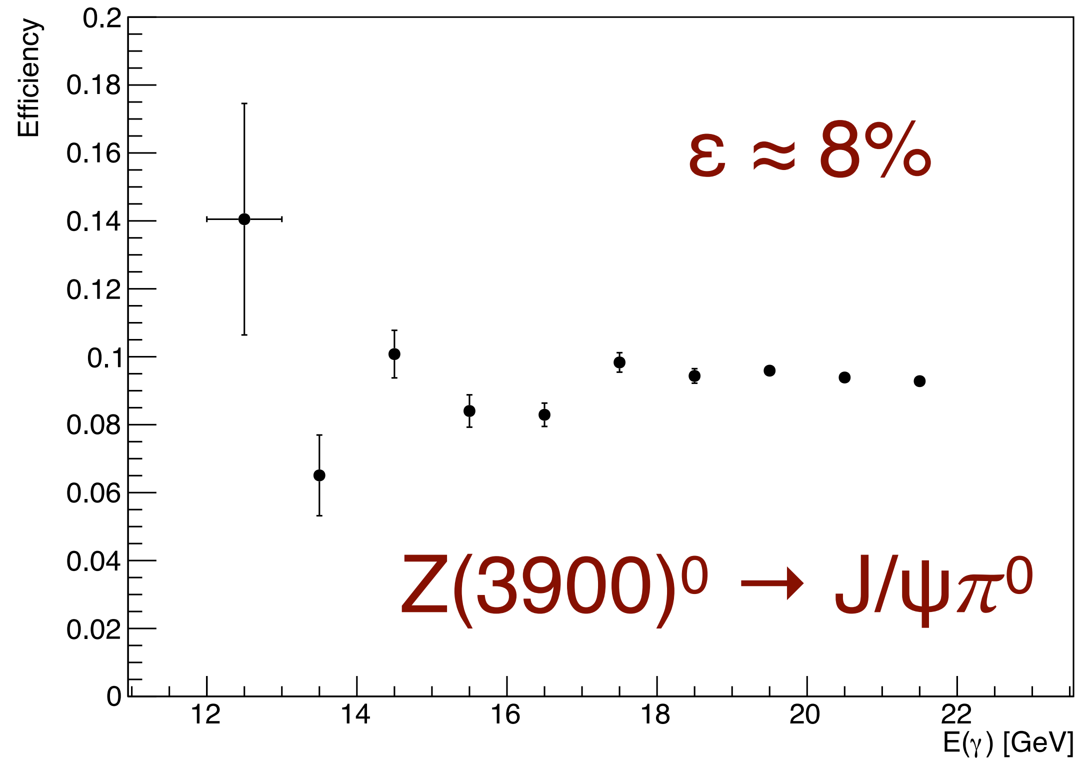


Efficiencies vs. Beam energy





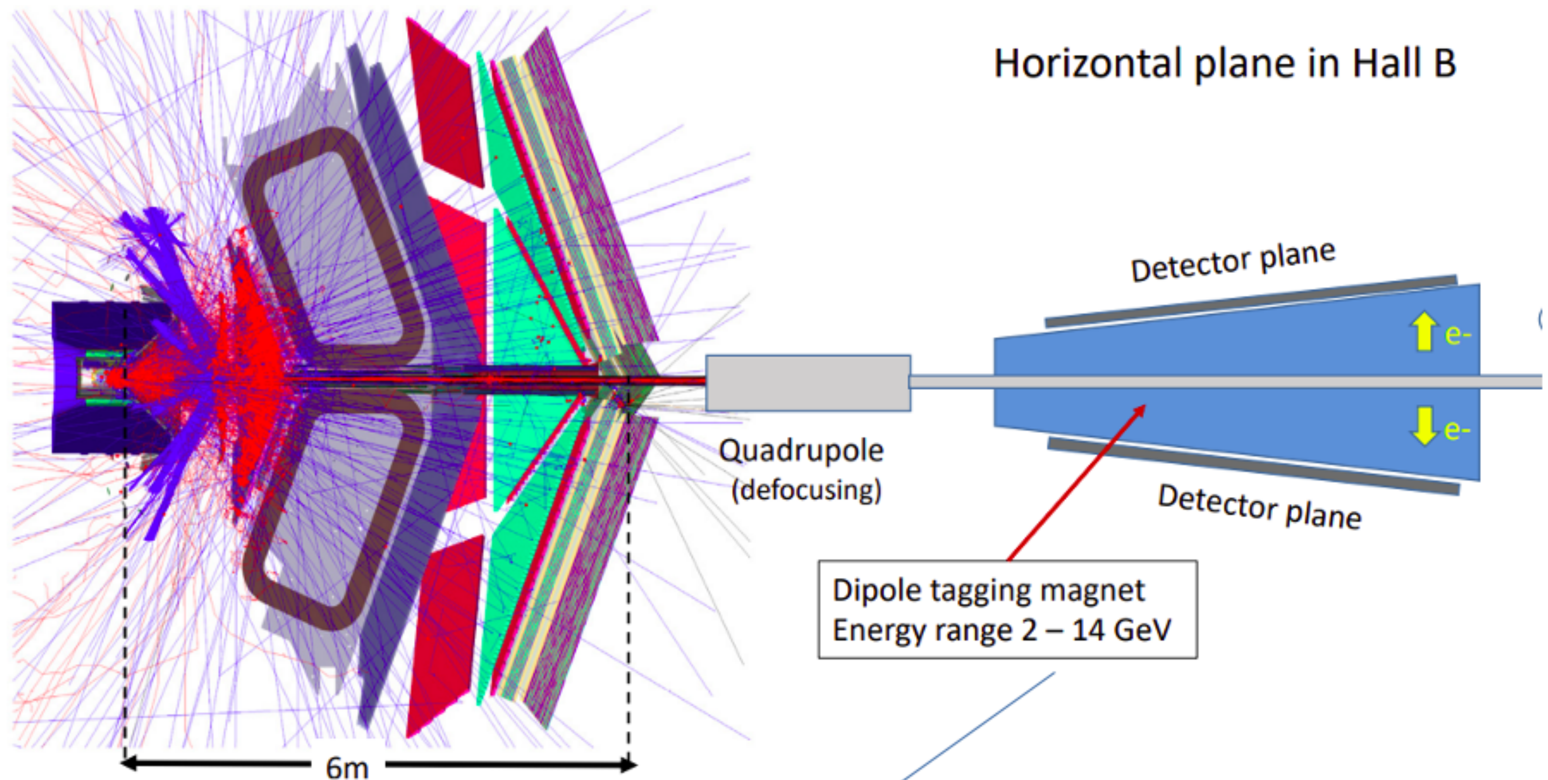




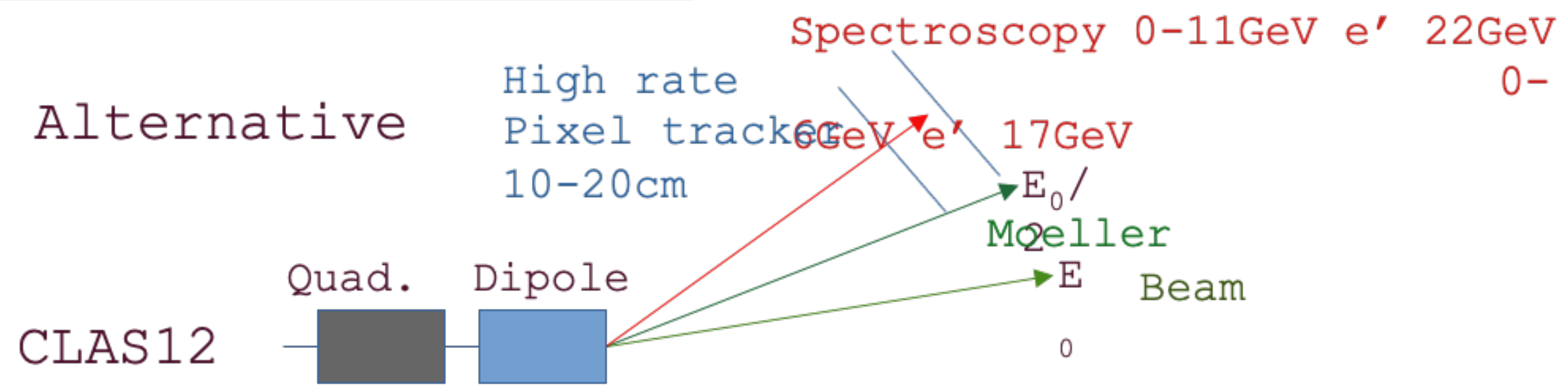
- n.b.: $\varepsilon(J/\psi \to e^+e^-) \approx 15 - 20$ %

Zero Degree Spectrometer

Courtesy: Burkert JFUTURE, Messina.



- Non-interacting electrons, Moller electrons, bremsstrahlung; electrons leave only accidental energy in CLAS12 detectors.
- Hadronically interacting electrons leave significant amount of energy and tracks in CLAS24, O(10GeV).
- The strategy would be to trigger on the event measured in CLAS24 detectors and tag those events with electrons measured in a 0-degree spectrometer.
- This should be studied in simulations to determine what magnitude in instantaneous luminosity can be achieved.
- Note that the Torus magnet open bore of ~ 4 cm accommodates ~0.5° scattering angle without interfering materials. * have assumed here can be increased to 0.75°



High low energy threshold
Will reduce results shown
Here, particularly for 17GeV