Recent GlueX Quarkonium Results and Prospects

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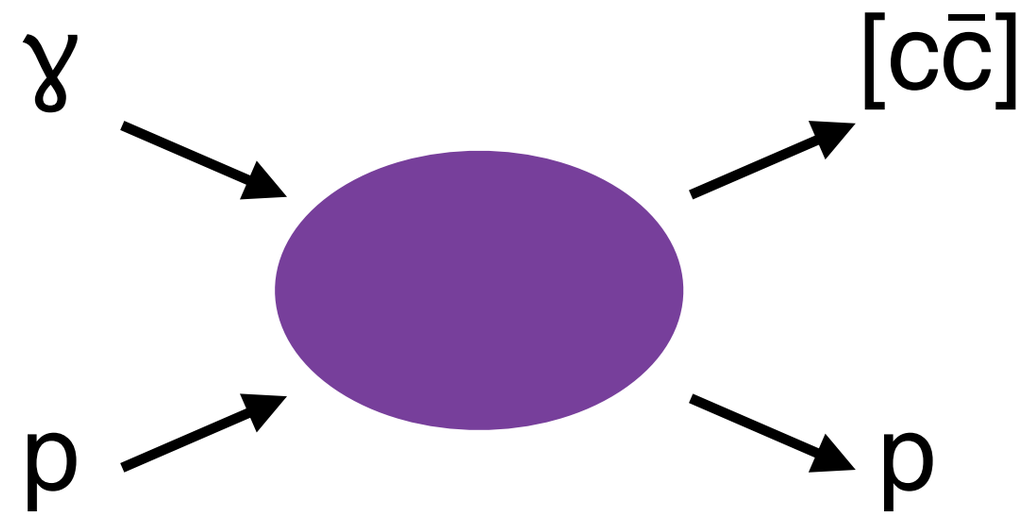
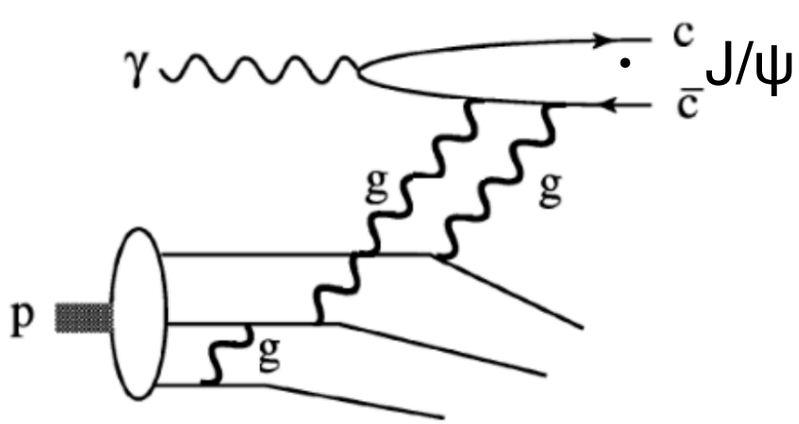
(for the GlueX Collaboration)

QWG2021 — The 14th International Workshop
on Heavy Quarkonium
March 19, 2021

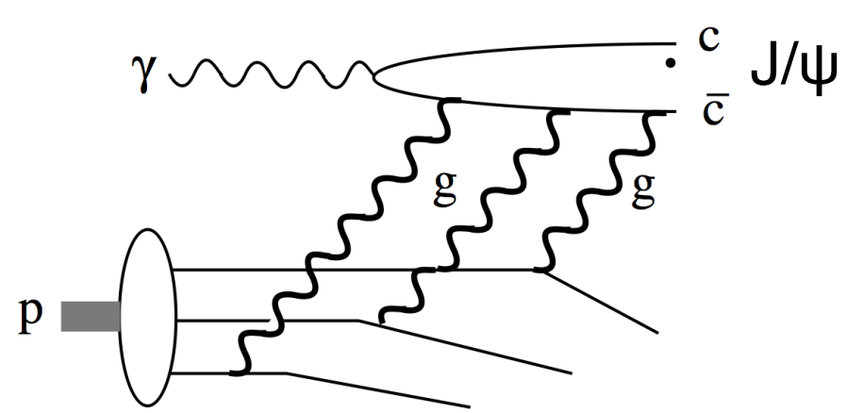
Charmonium Photoproduction Near Threshold

- Near-threshold production is ideal for studying the $c\bar{c}$+N interaction
  - Probes the distribution of gluons in the proton and the nature of the proton mass
  - Understanding the nature of QCD confinement





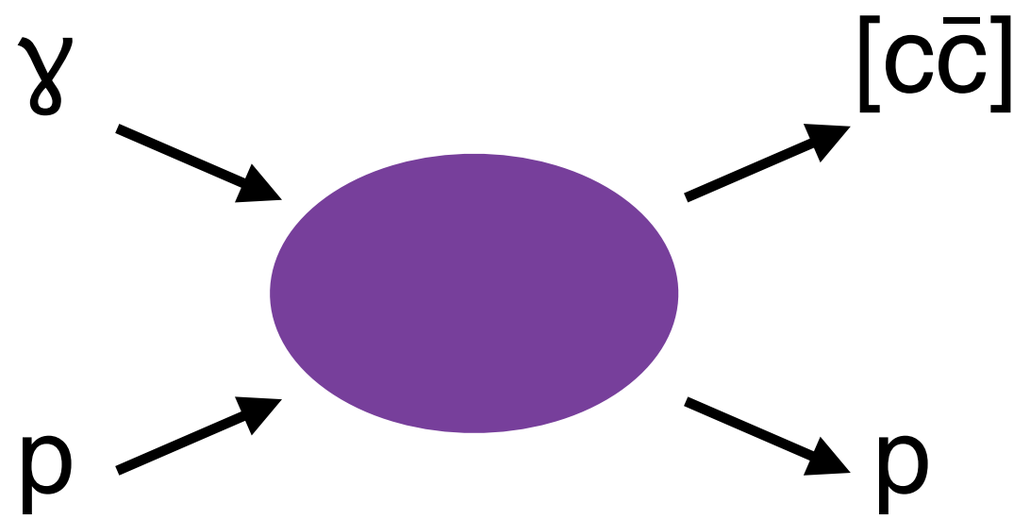
leading-twist

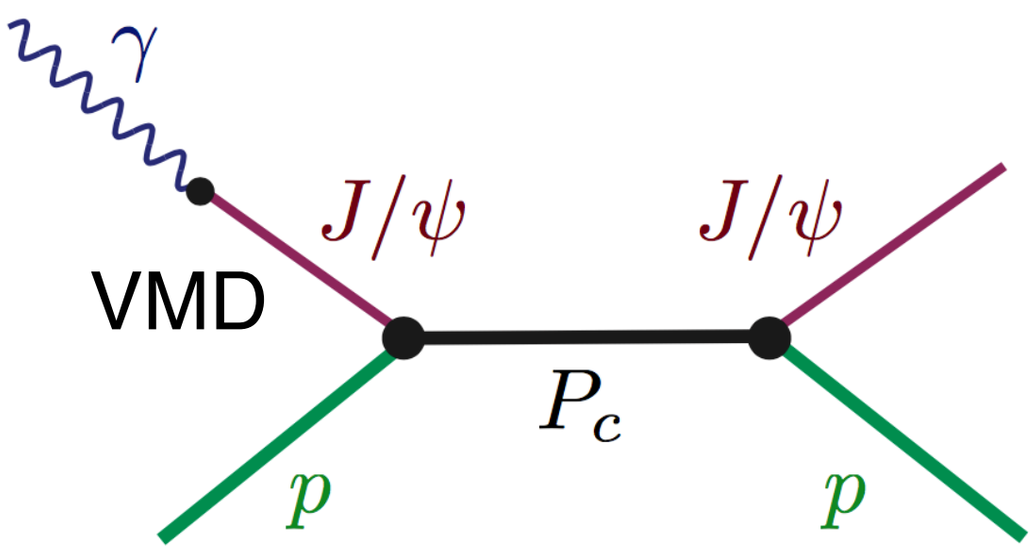


higher-twist

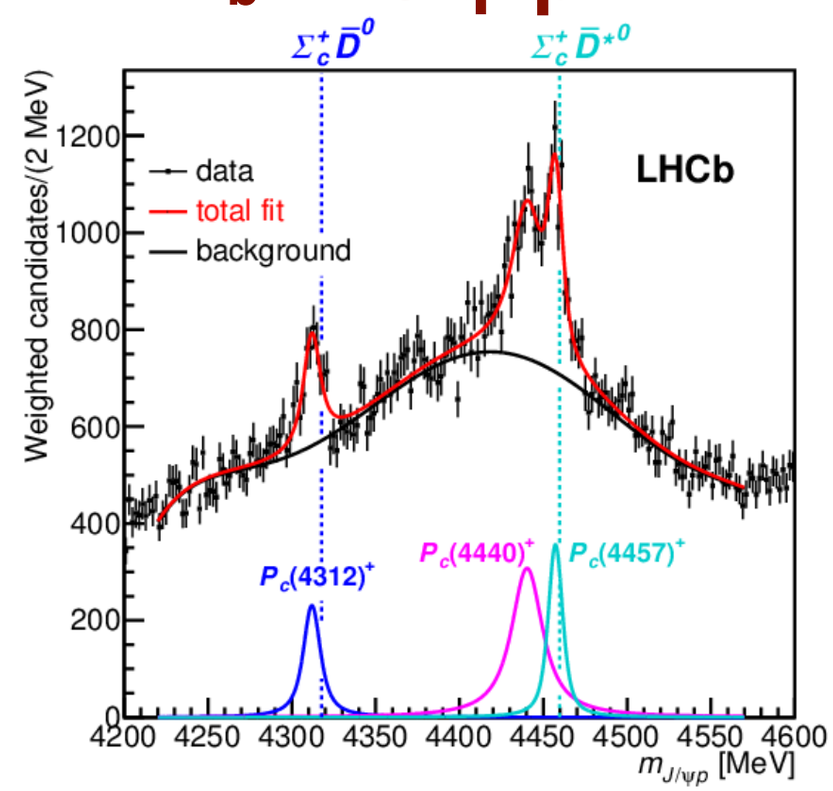
Charmonium Photoproduction Near Threshold

- Near-threshold production is ideal for studying the $c\bar{c}$+N interaction
  - Can look for s-channel production of resonant states, extend understanding of 5-quark interaction



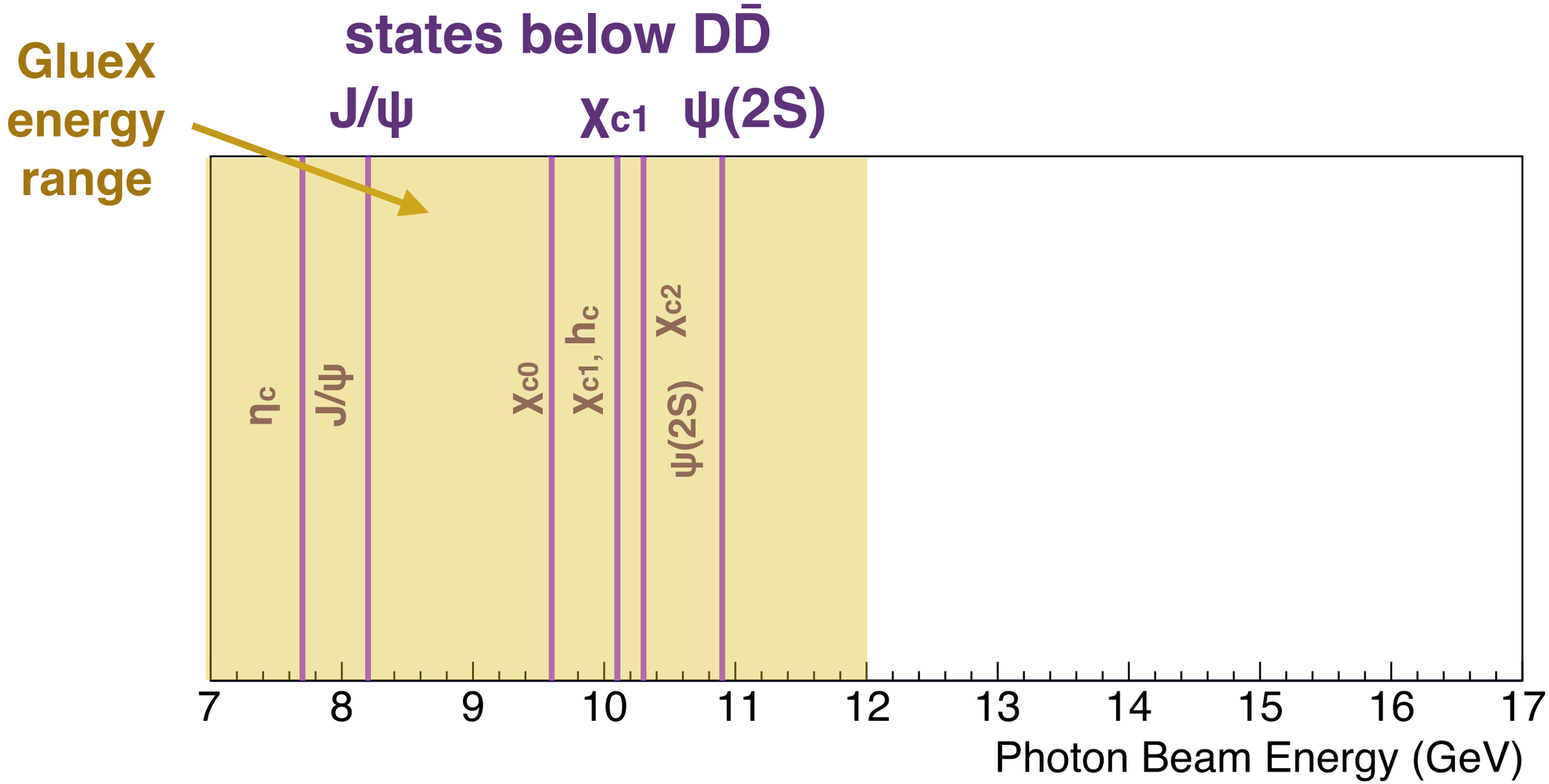


$\Lambda_b \to J/\psi\, p\, K^-$



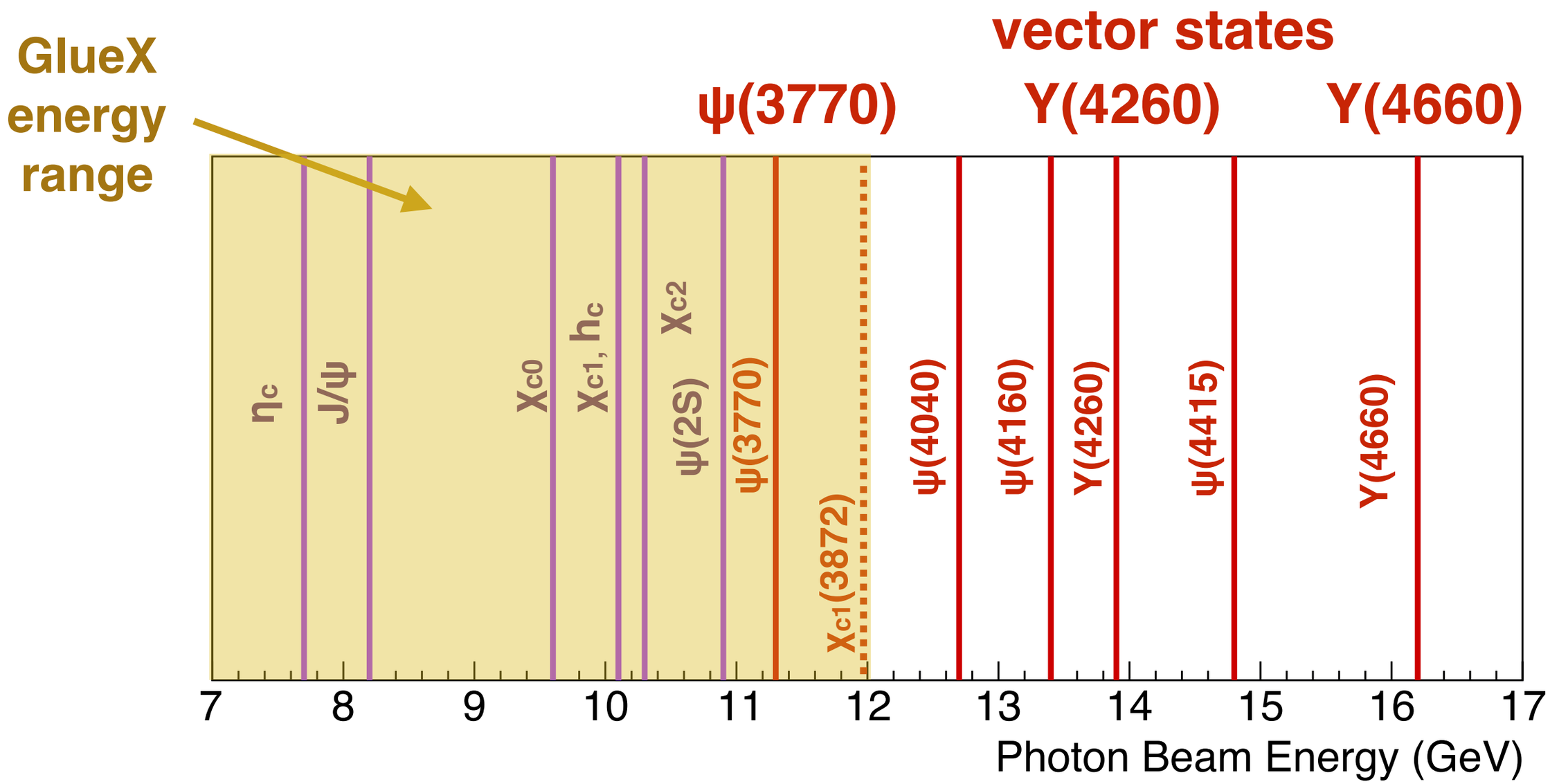
LHCb, PRL 122, 222001 (2019)

Charmonium Photoproduction Near Threshold



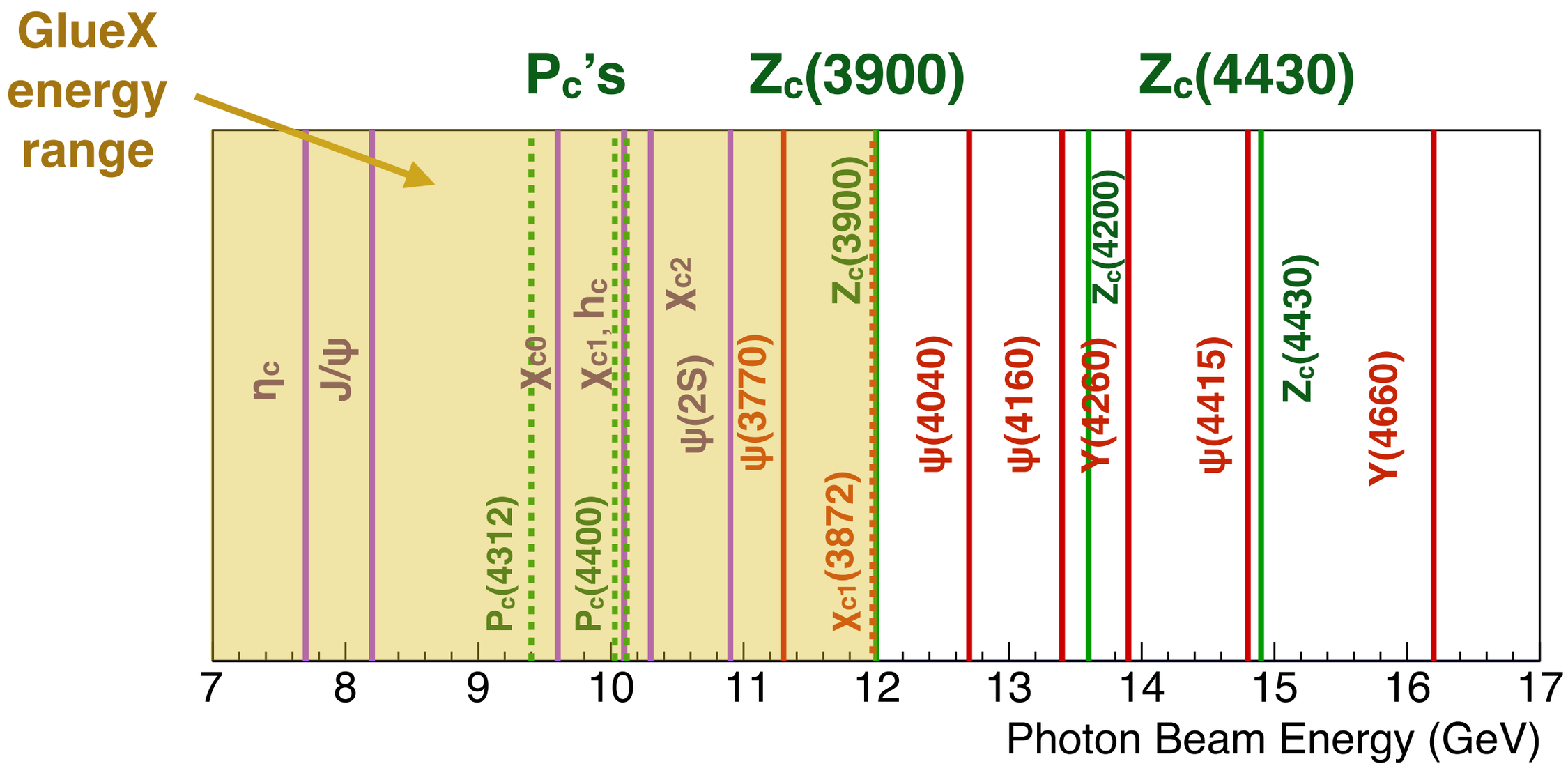
- GlueX energy range: $E_\gamma < 12$ GeV
- Large hadronic background, focus on decays containing $J/\psi \rightarrow e^+e^-$

Charmonium Photoproduction Near Threshold



- Thresholds for states above the $D\bar{D}$ threshold extend to higher energies

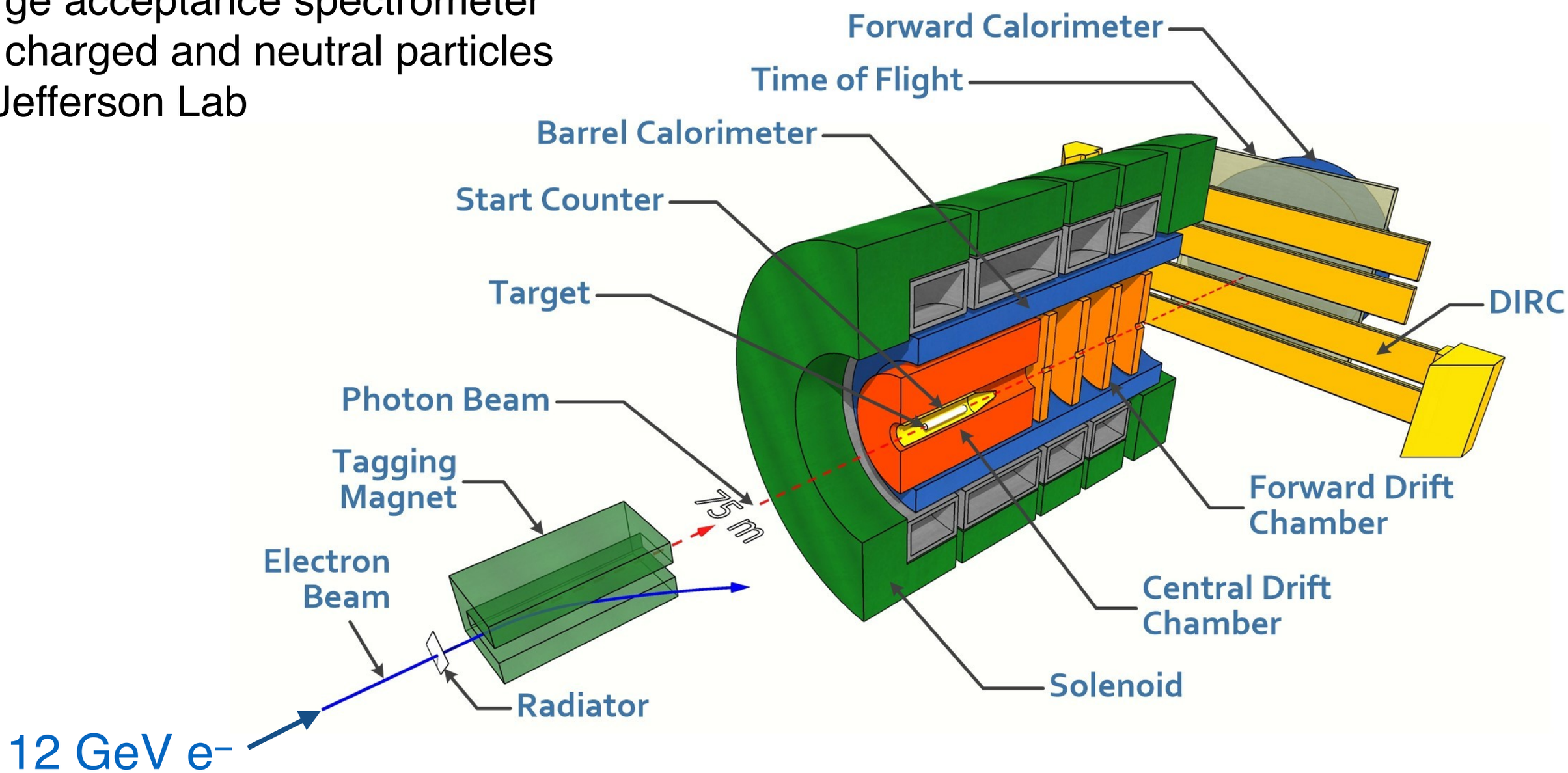
Charmonium Photoproduction Near Threshold



- Also have access to production of P_c's

The GlueX Experiment

Large acceptance spectrometer for charged and neutral particles at Jefferson Lab



- **GlueX-I (2017–2018): $E_\gamma > 8$ GeV, L = 330 pb^{-1}**
- **GlueX-II (2020–): expect 3-4x GlueX-I**

The GlueX Experiment

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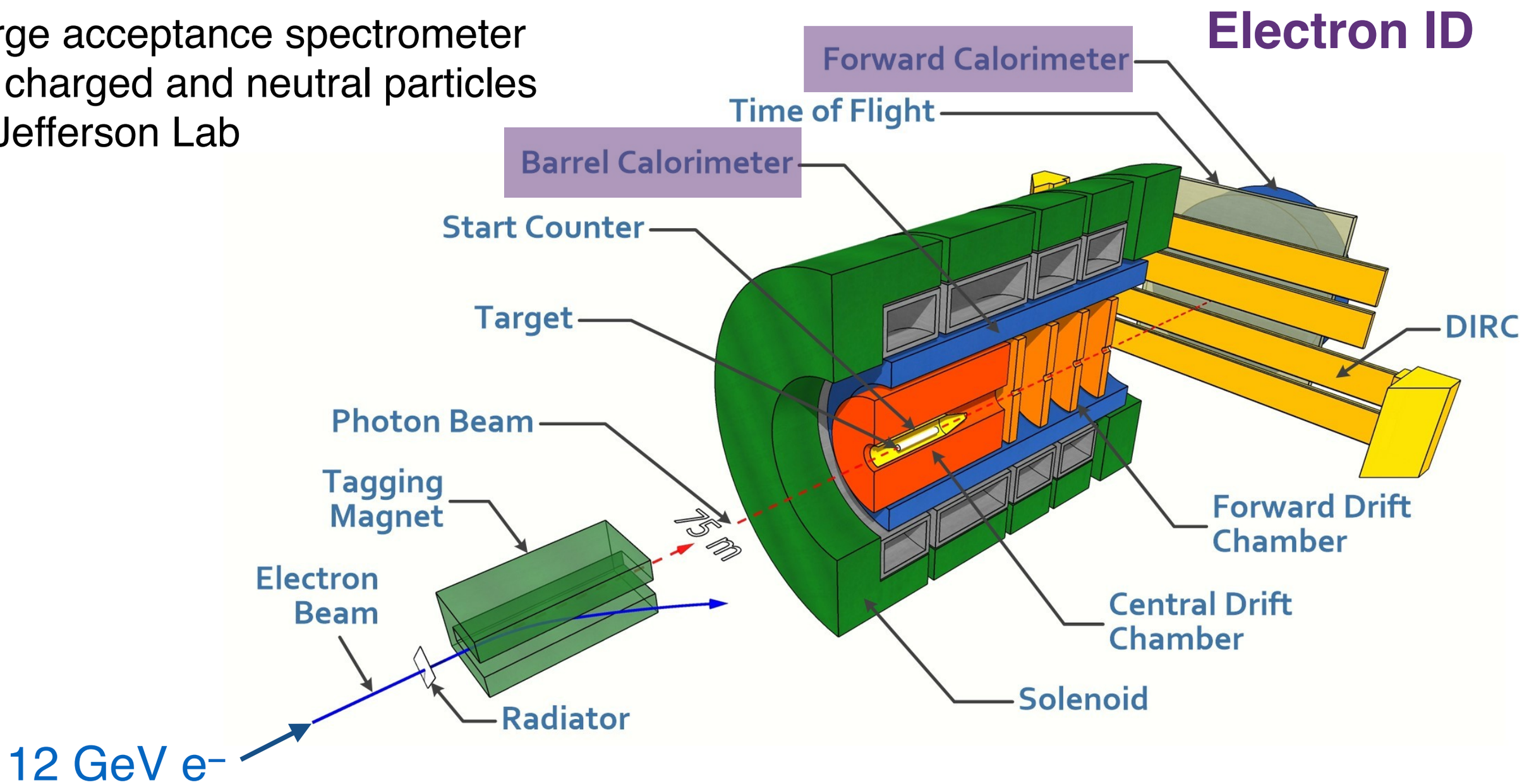

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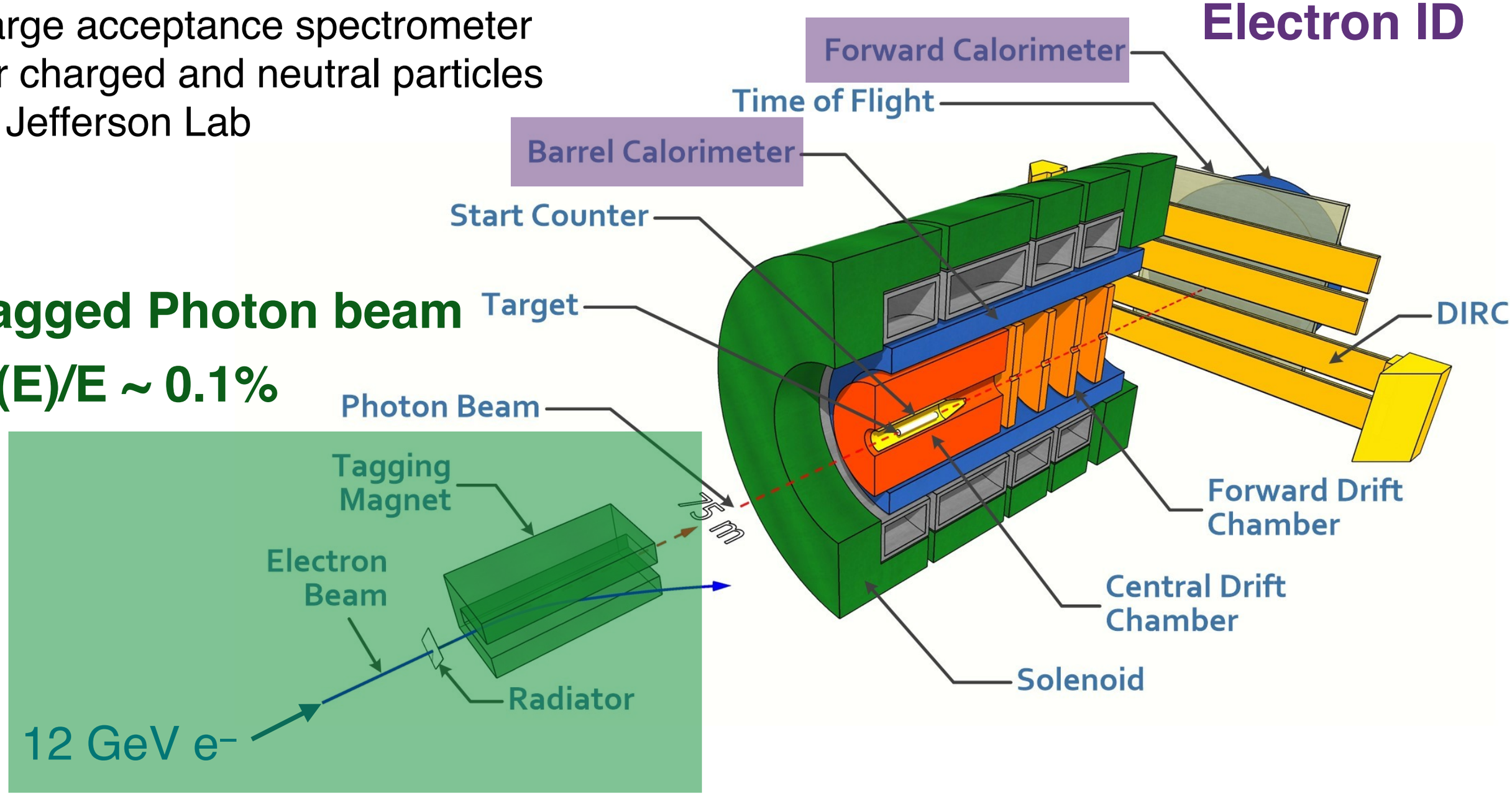
The GlueX Experiment

Large acceptance spectrometer for charged and neutral particles at Jefferson Lab

Electron ID

Tagged Photon beam

$\sigma(E)/E \sim 0.1\%$



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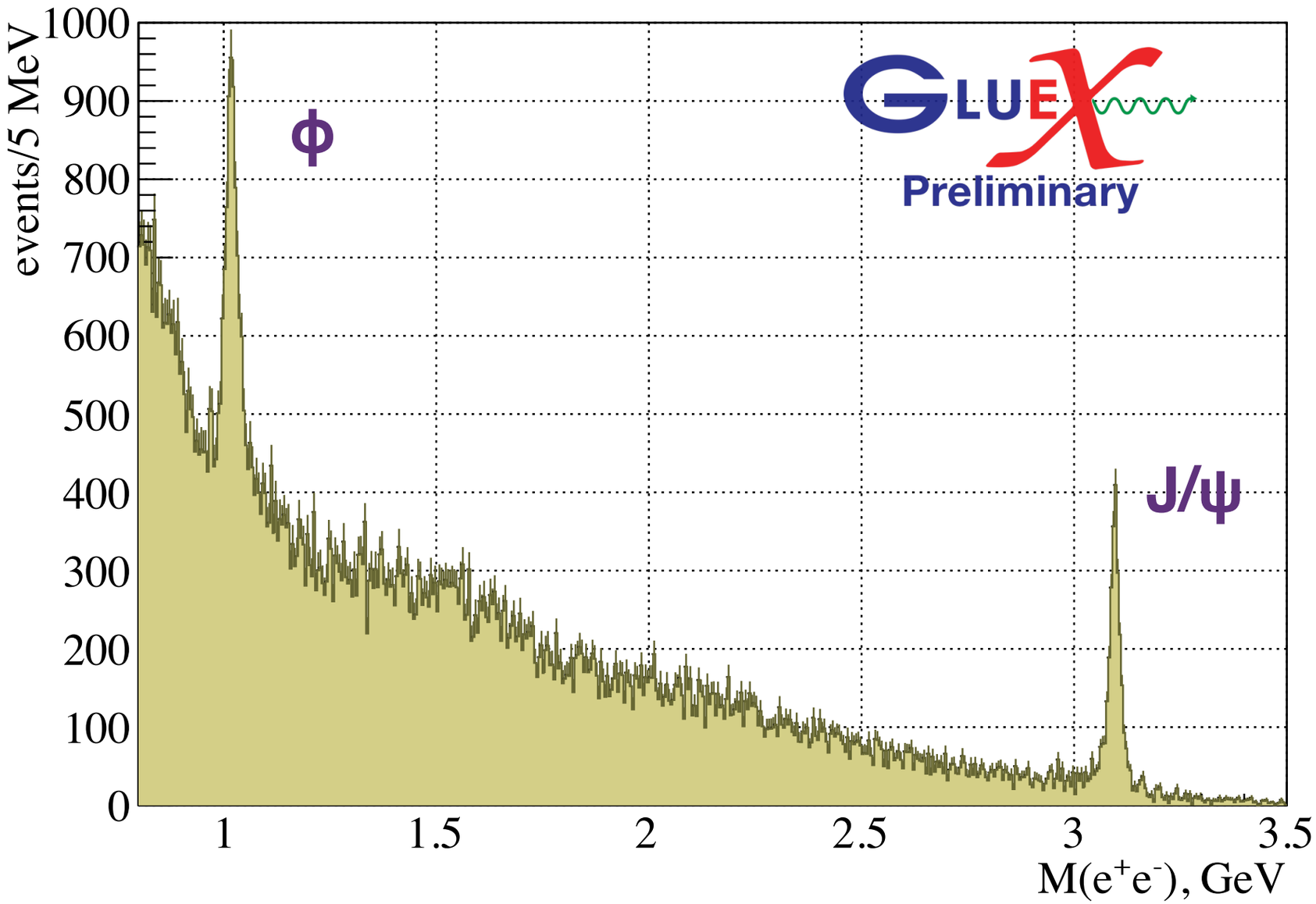
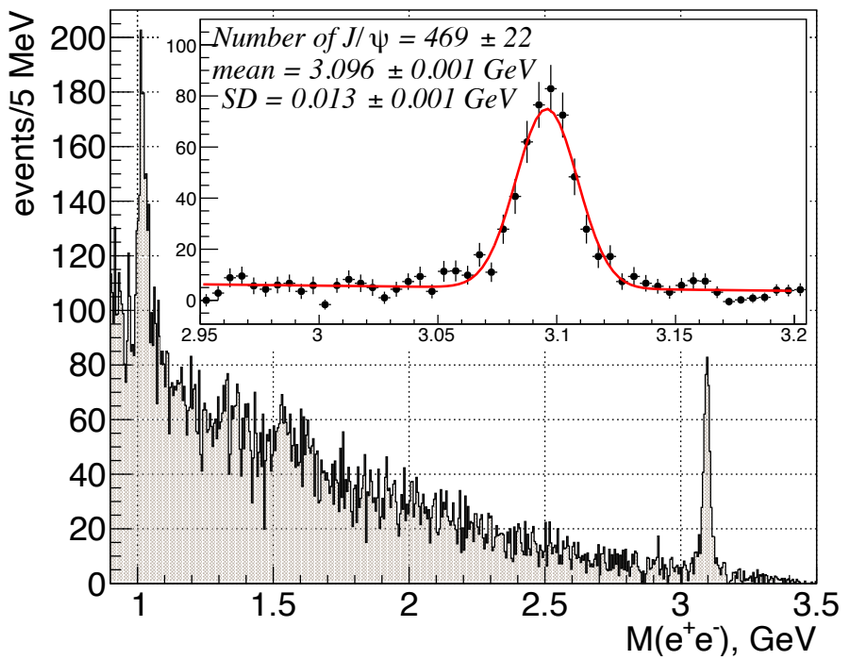
J/ψ Photoproduction at GlueX: Mass Spectrum



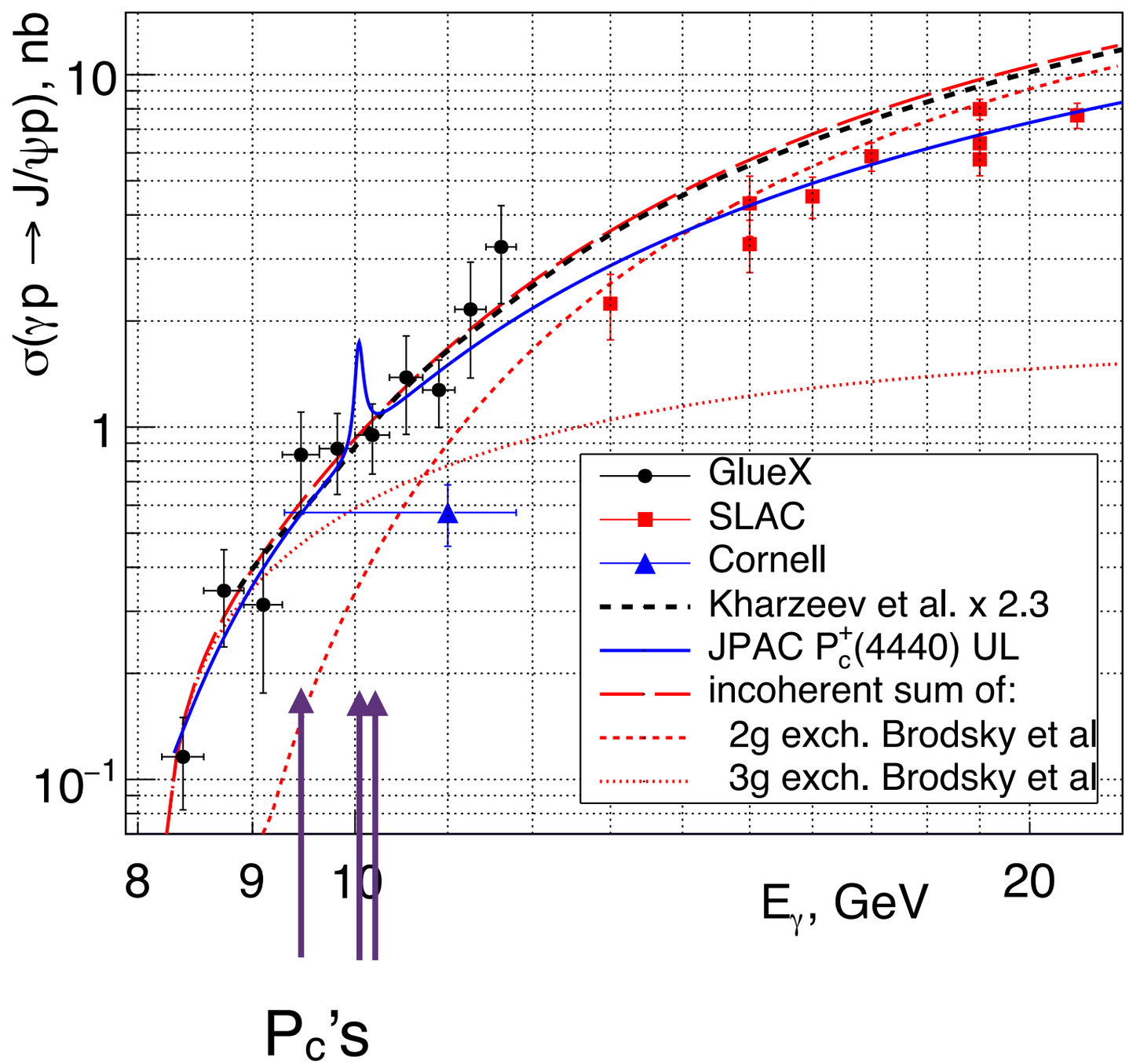
- Reconstruct **p γ → p + J/ψ, J/ψ → e^+e^-**
- Calculate J/ψ cross sections normalized by non-resonant e^+e^-

Published GlueX J/ψ Photoproduction Results



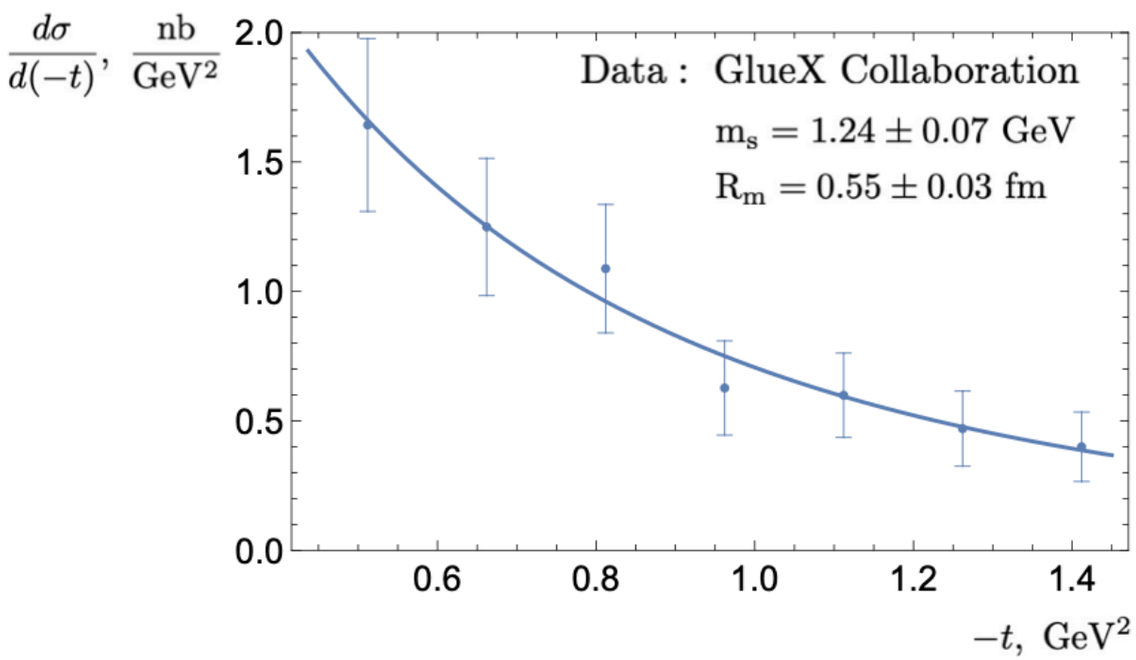
- Used portion of GlueX-I data [469 J/ψ] to measure cross sections
- 27% normalization uncertainty
- Model-dependent limits set on P_c production

GlueX: PRL 123, 072001 (2019)



Interpretations of GlueX J/ψ Photoproduction Results

Kharzeev, arXiv:2102.00110 (2021)

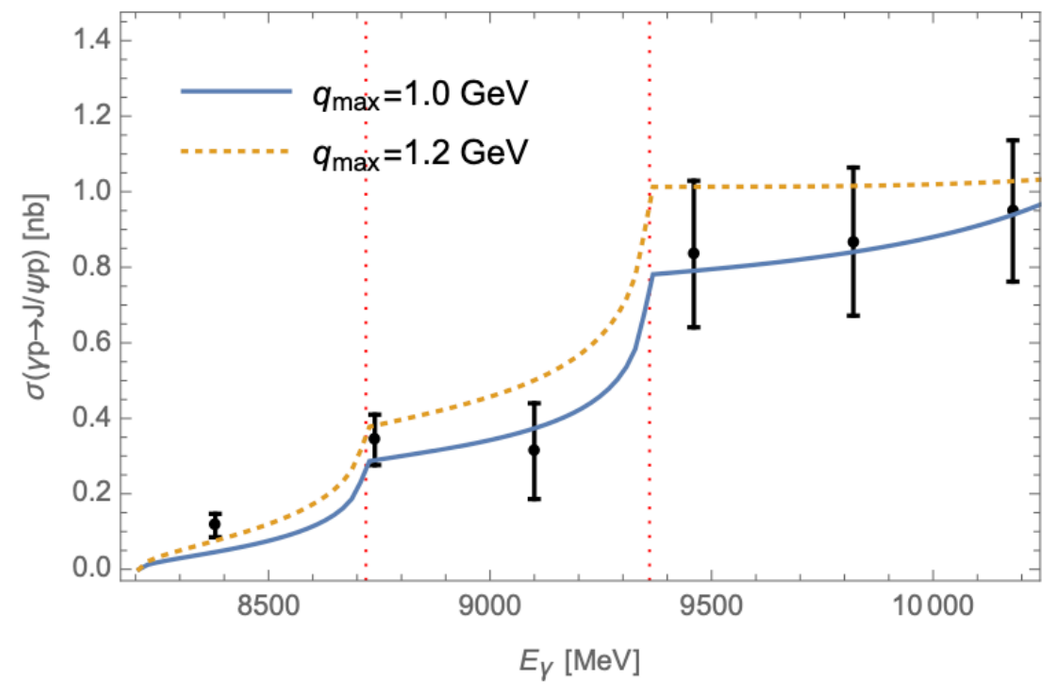


mass radius: $R_m = 0.55 \pm 0.03$ fm

charge radius: $R_c = 0.8409 \pm 0.0004$ fm

More data closer to the threshold is needed

Du et al., EPJC 80, 1053 (2020)



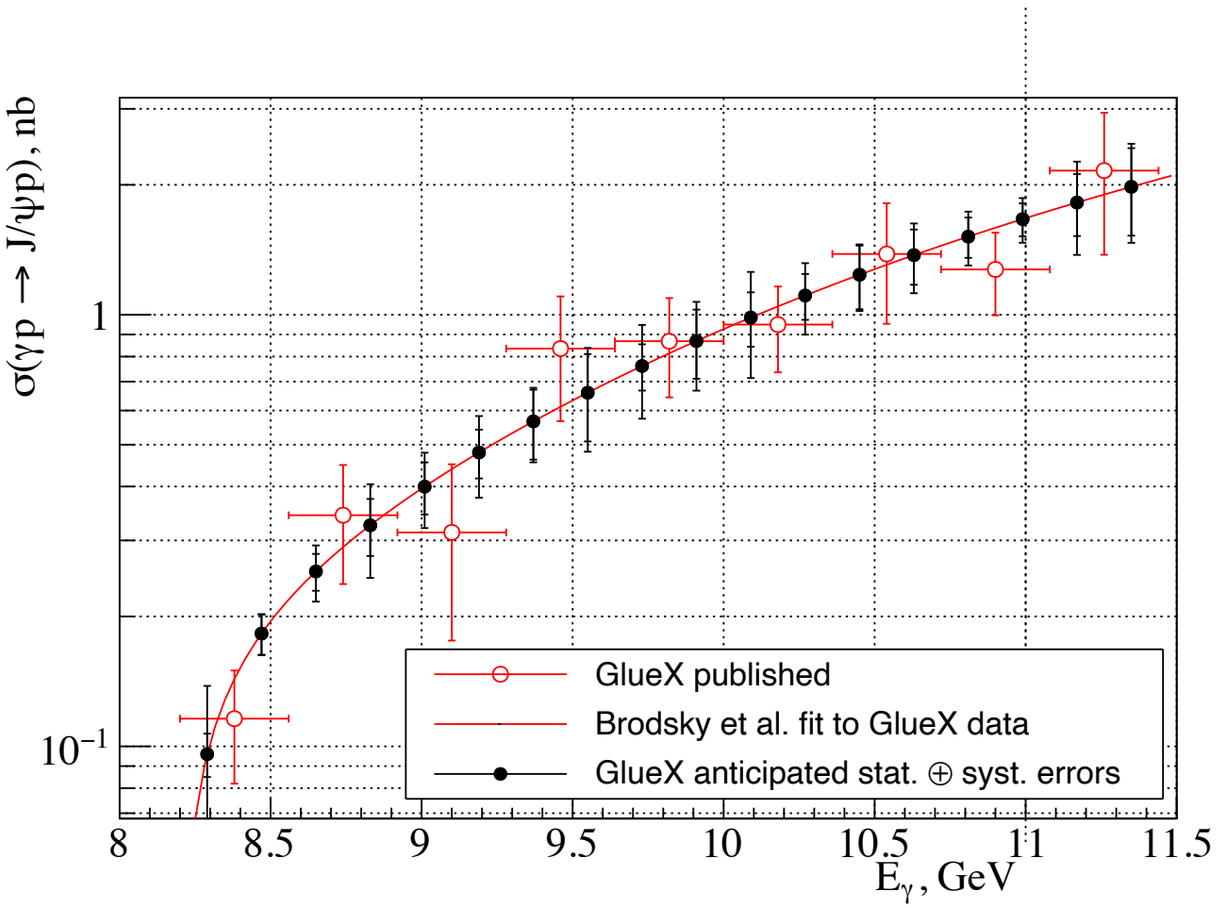
Calculated cross section energy dependence including open charm loops

Higher precision data is needed

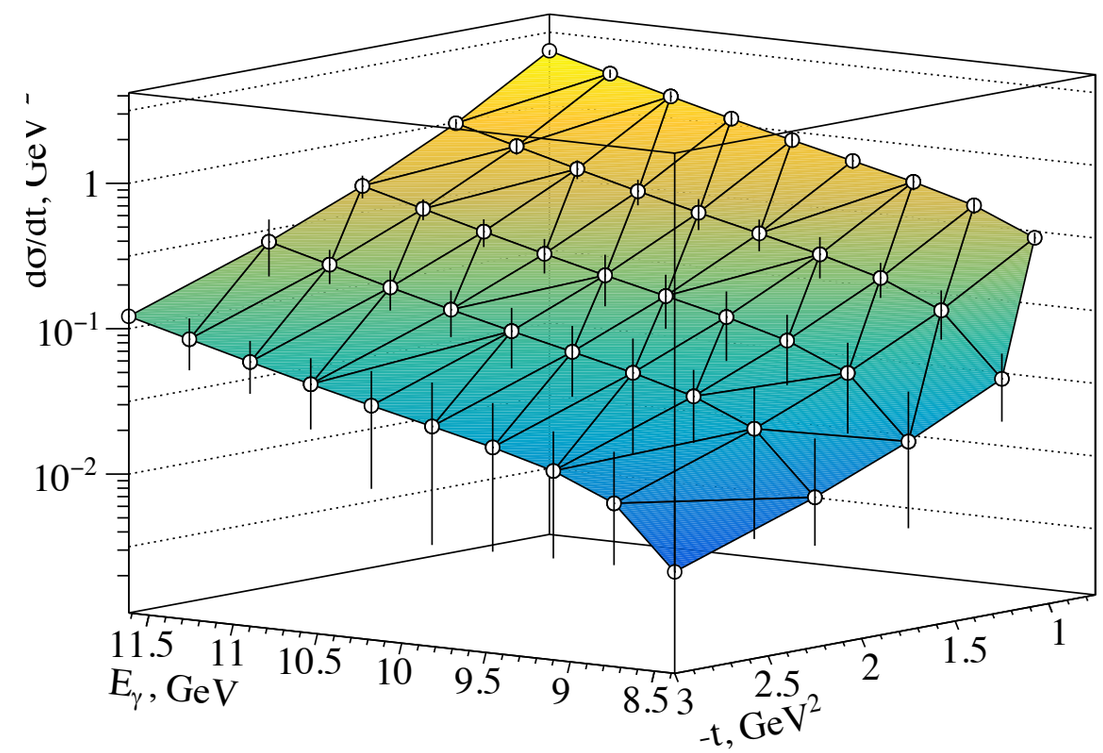
- Lots of interest in these measurements—selected results shown above

Projected GlueX-I J/ψ Photoproduction Results

Estimated errors using full GlueX-I data



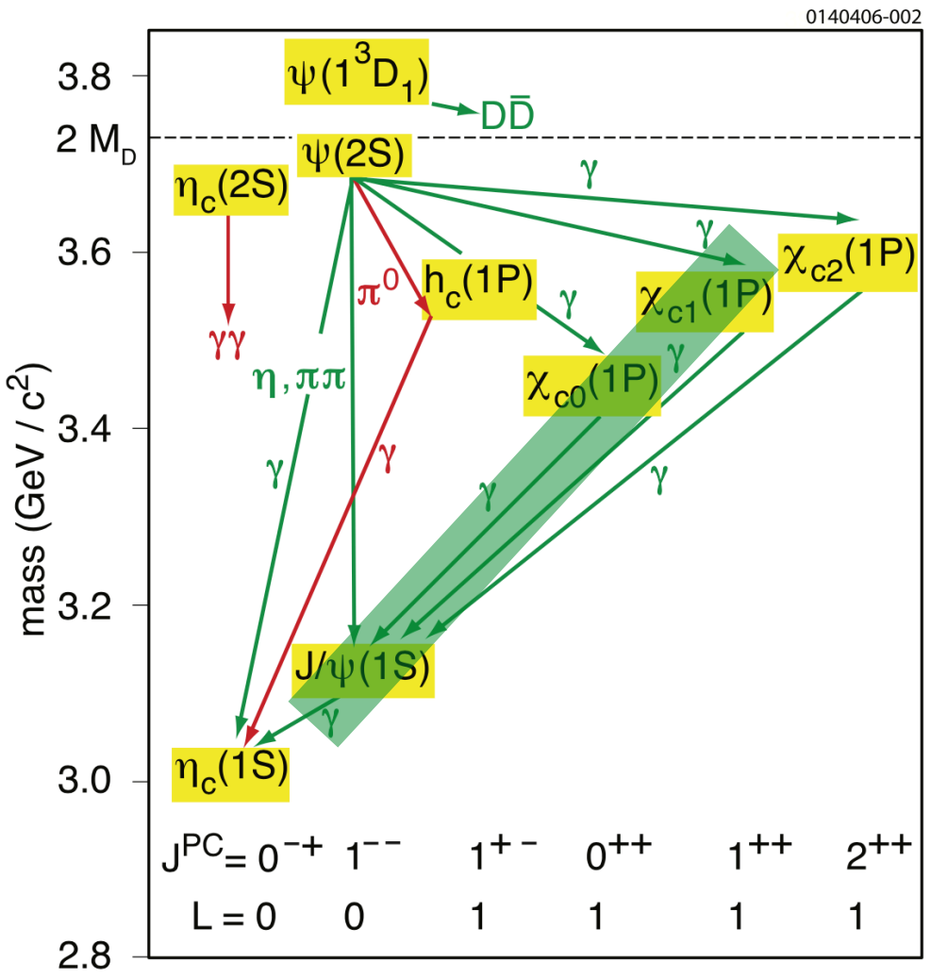
ERRORS ONLY shown for 2D differential cross-sections



Estimated errors using energy dependence from published results and dipole t-dependence

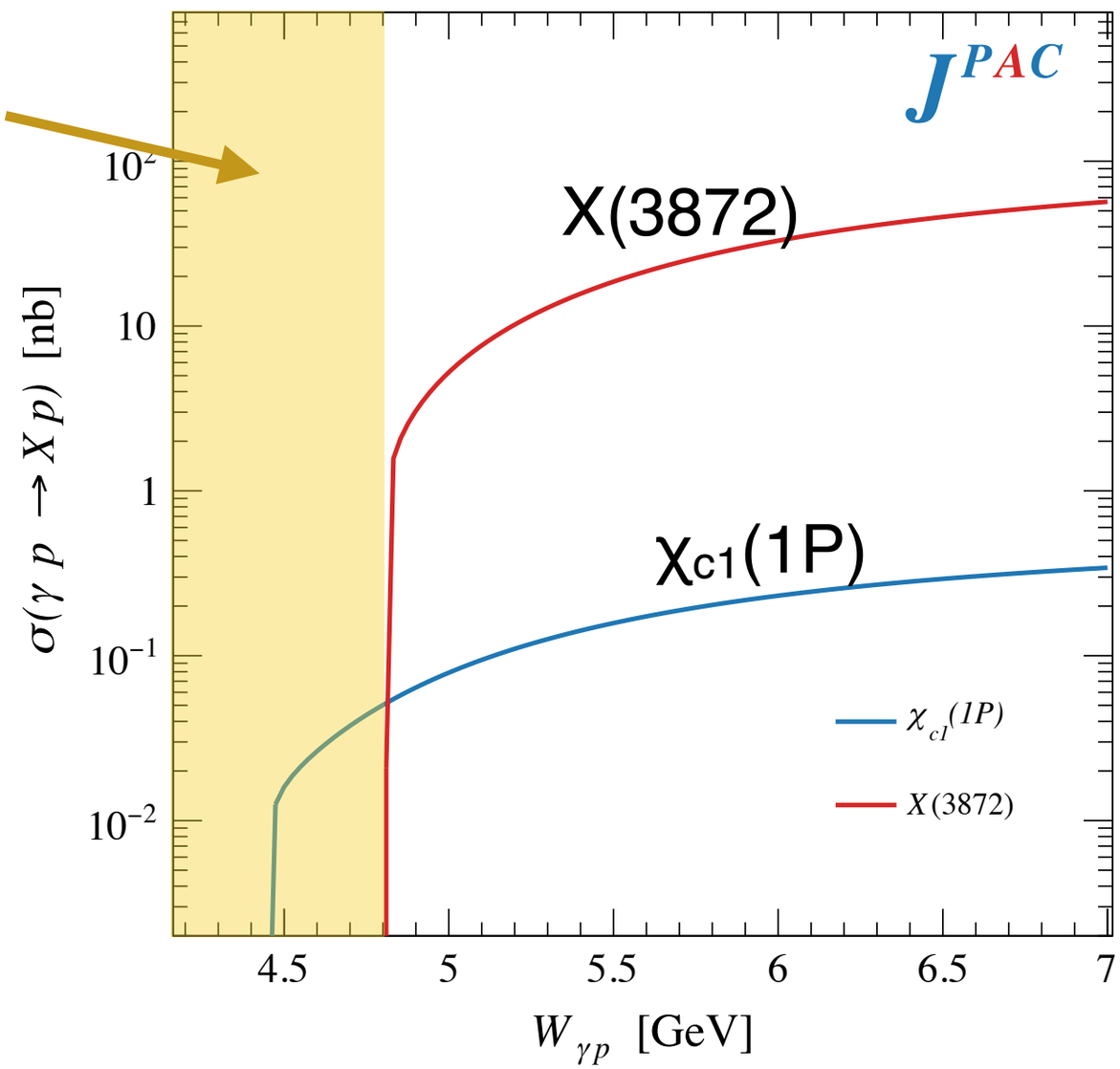
- Full GlueX-I run has 2k J/ψ, expect updated results soon!
- Measurement of cross section t-dependence benefits from additional data

$\chi_{c1}(1^3P_1)$ Photoproduction at GlueX



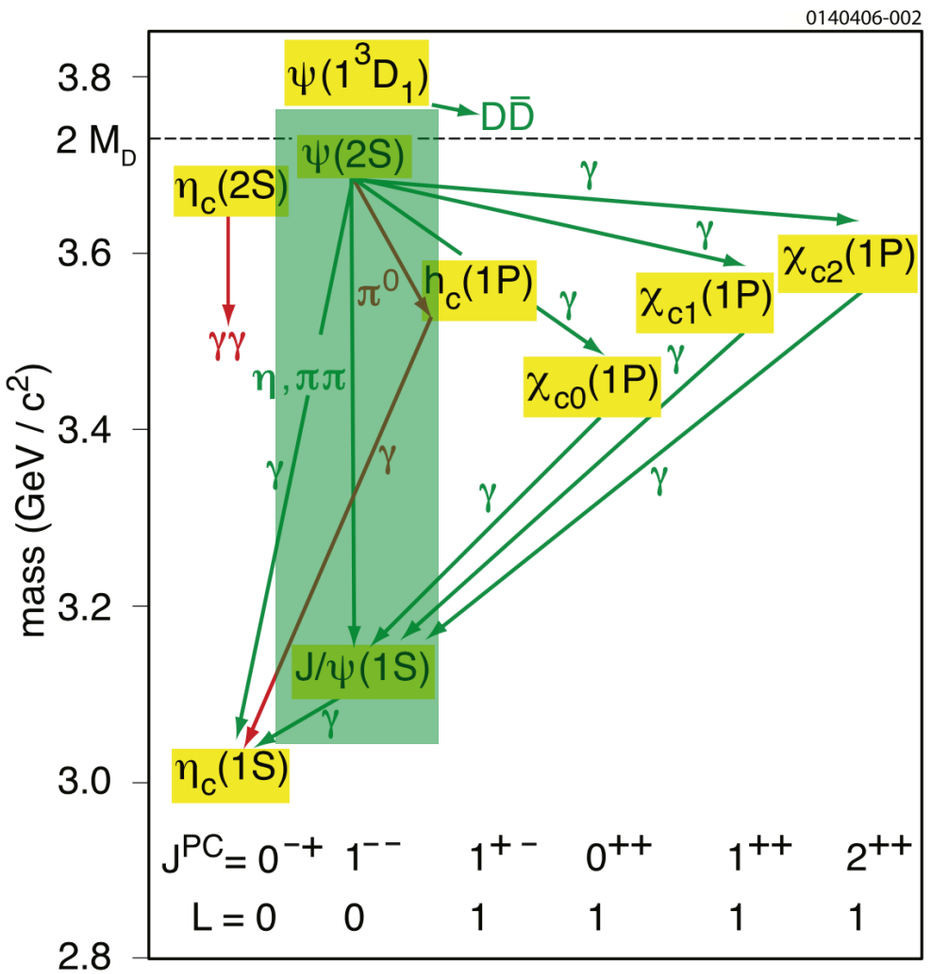
GlueX energy range

JPAC: PRD 102, 114010 (2020)



- $\chi_{c1}(1^{++})$ photoproduction: probe of different parity, P_c search
- JPAC model estimate using known $\chi_{c1} \rightarrow \gamma(\rho,\omega,\phi,J/\psi)$ couplings
- GlueX-I expectation: $N(\chi_{c1} \rightarrow \gamma J/\psi,\ J/\psi \rightarrow e^+e^-) = O(50)$

$\psi(2^3S_1)$ Photoproduction at GlueX



GlueX energy range

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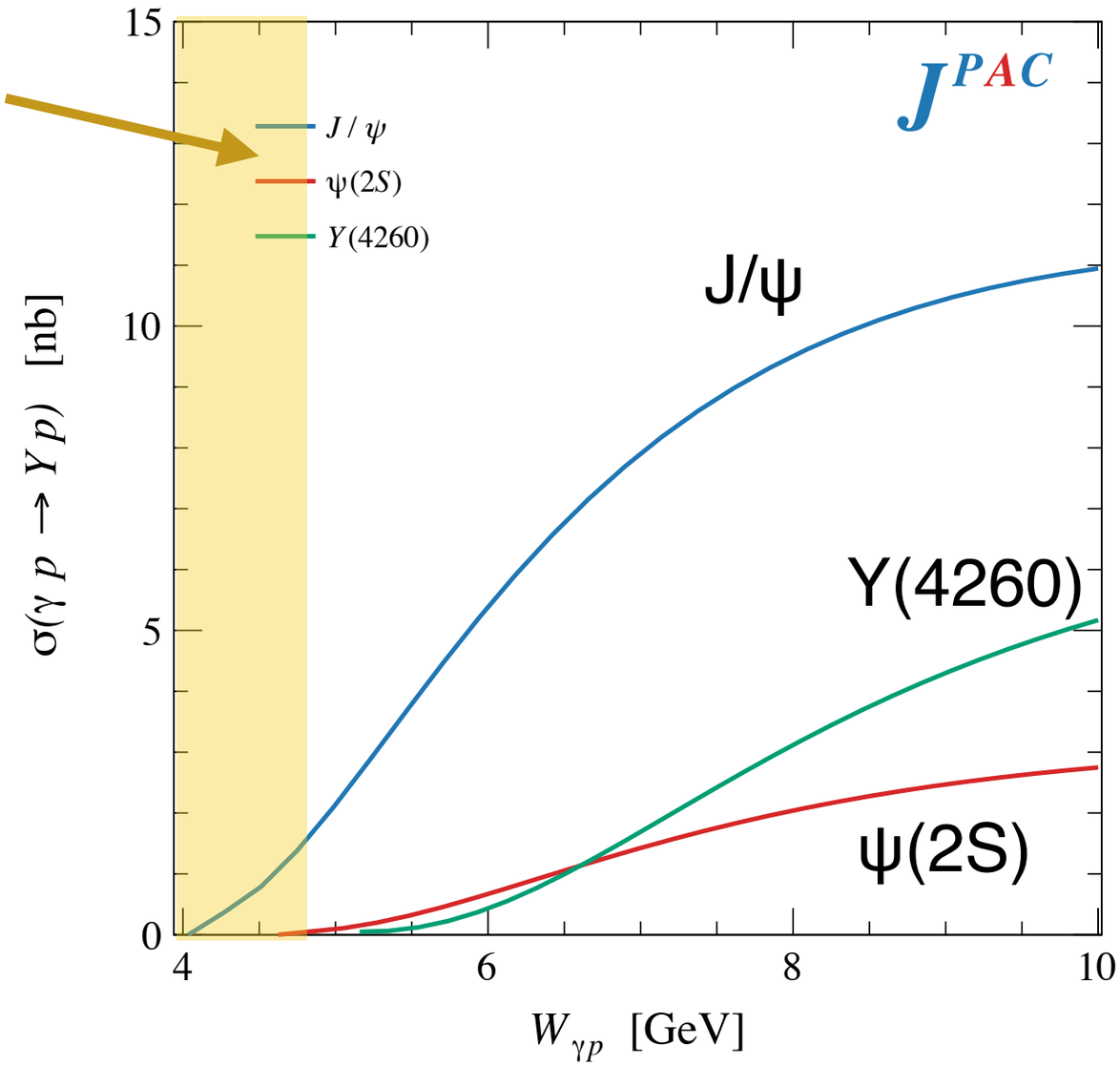


- $\psi(2S)$ photoproduction: probe of wave function dependence
- JPAC model estimates using known $\Gamma_{\gamma gg}(\psi(2S)) / \Gamma_{\gamma gg}(J/\psi)$
- GlueX-I expectation: $N(\psi(2S) \rightarrow \pi^+\pi^- J/\psi,\ J/\psi \rightarrow e^+e^-) < 10$

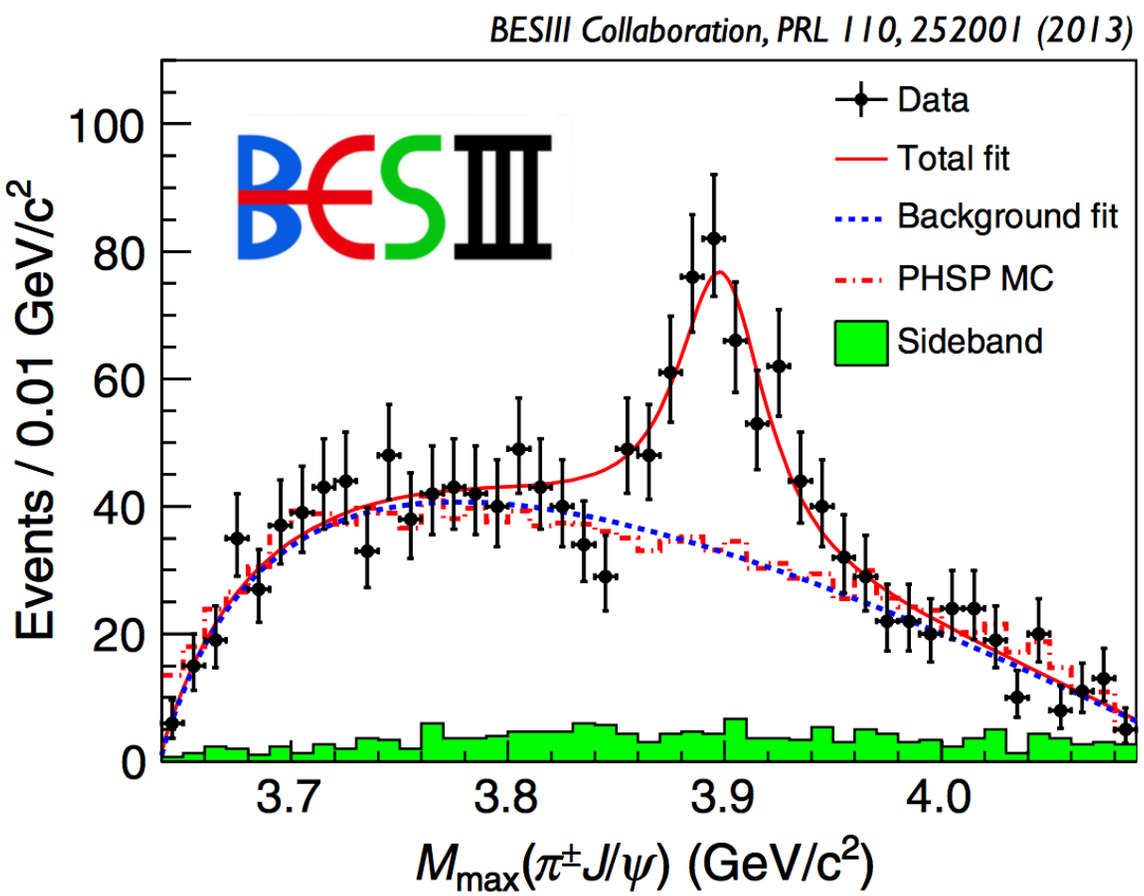
Summary and Prospects

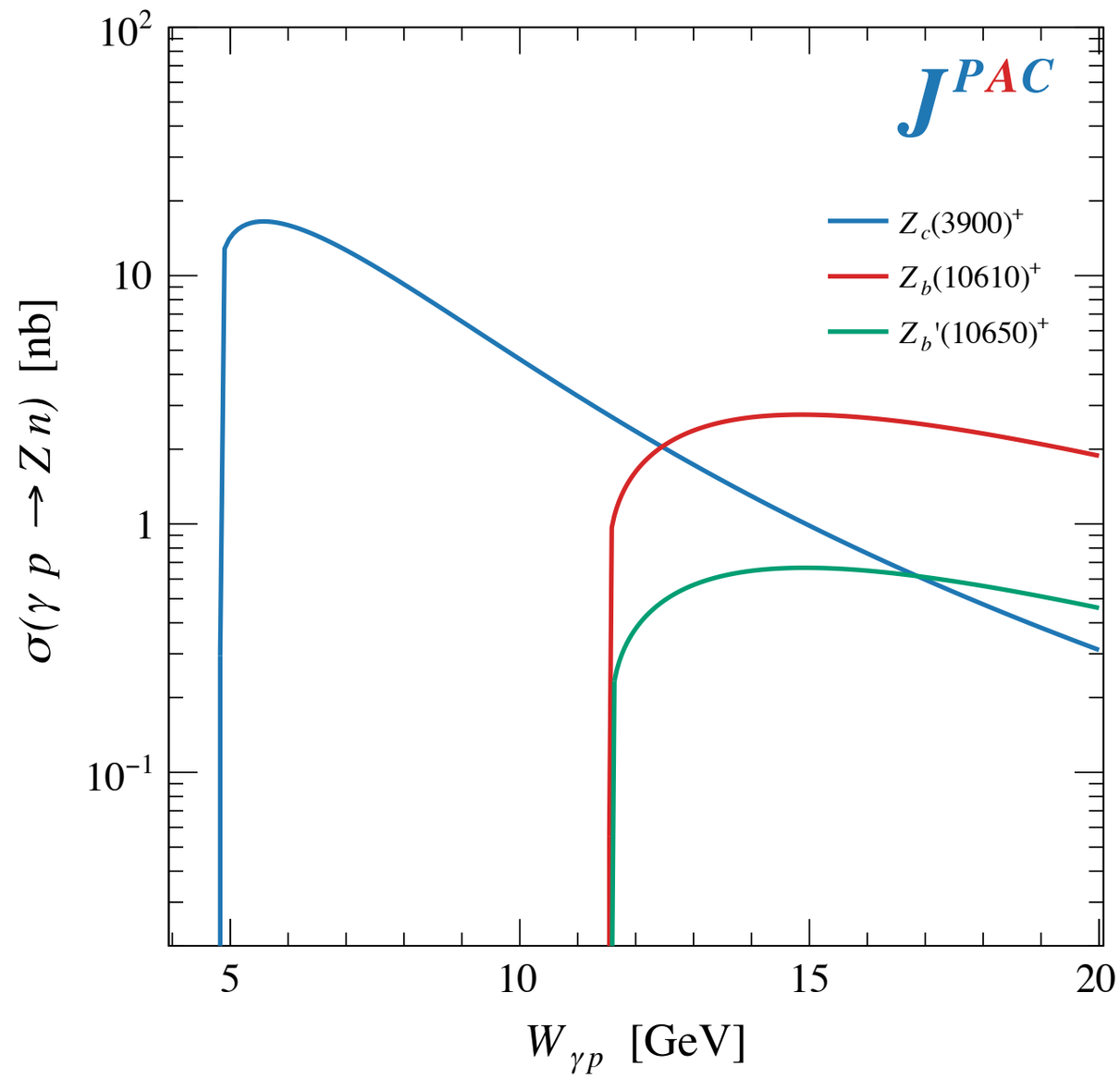
- GlueX has made the first measurement of the energy dependence of the J/ψ cross section near threshold
  - Expect an update soon with the full 2k J/ψ from GlueX-I
  - The ongoing GlueX-II run allows us to measure $d\sigma / dt\, dE$
- Other measurements of bound charmonia are possible with the growing GlueX data set
  - χ_{c1} and $\psi(2S)$ appear feasible
  - Other ideas: production off Δ's, deuteron/nuclear targets, …
  - Open charm: exciting possibility but very difficult due to small b.f.'s, large background levels, GlueX-II DIRC will help…
- Exploring near-threshold photoproduction of other charmonia requires a higher-energy machine or an EIC

Backup Slides

Zc Photoproduction at GlueX

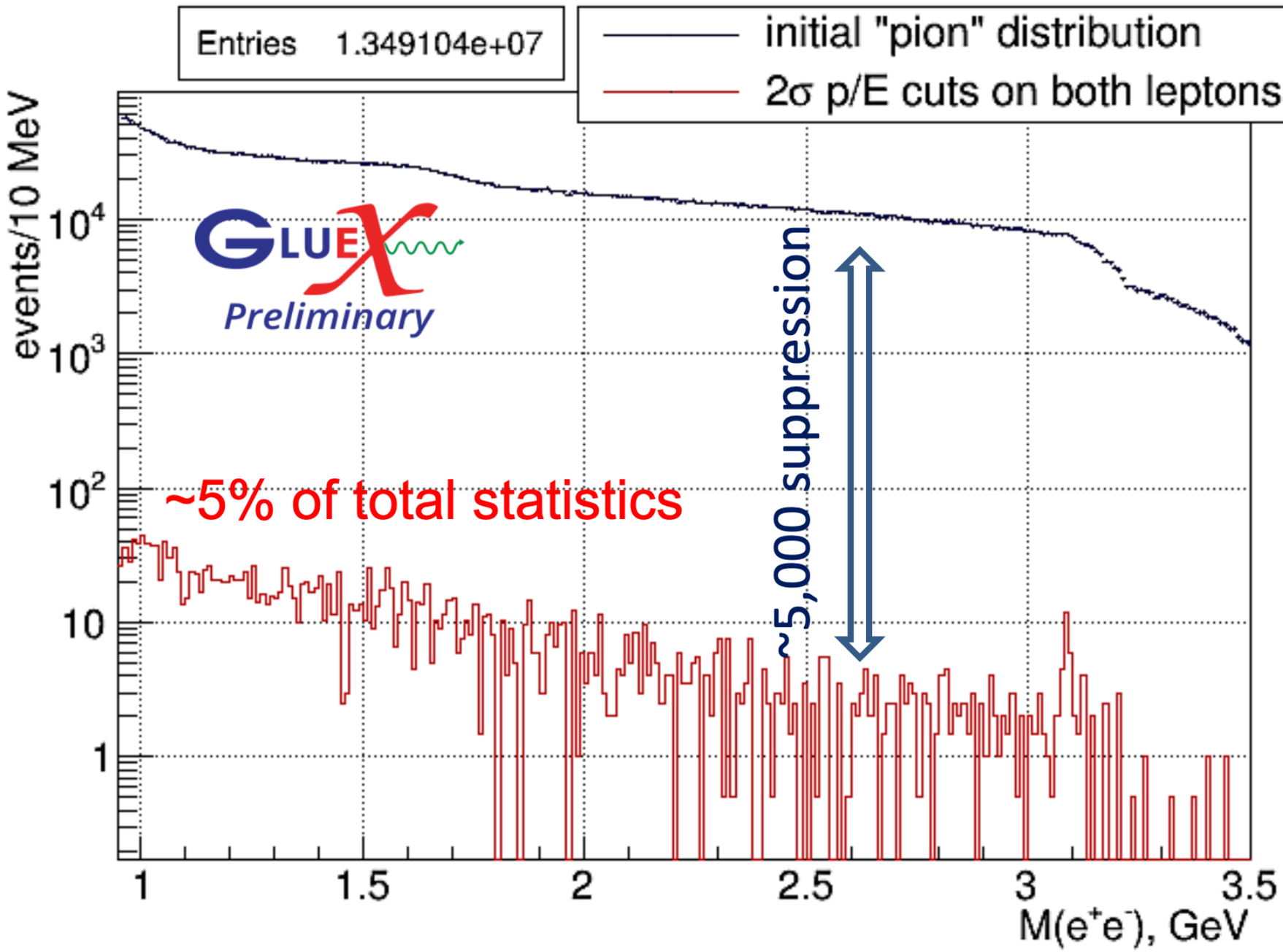
JPAC: PRD 102, 114010 (2020)



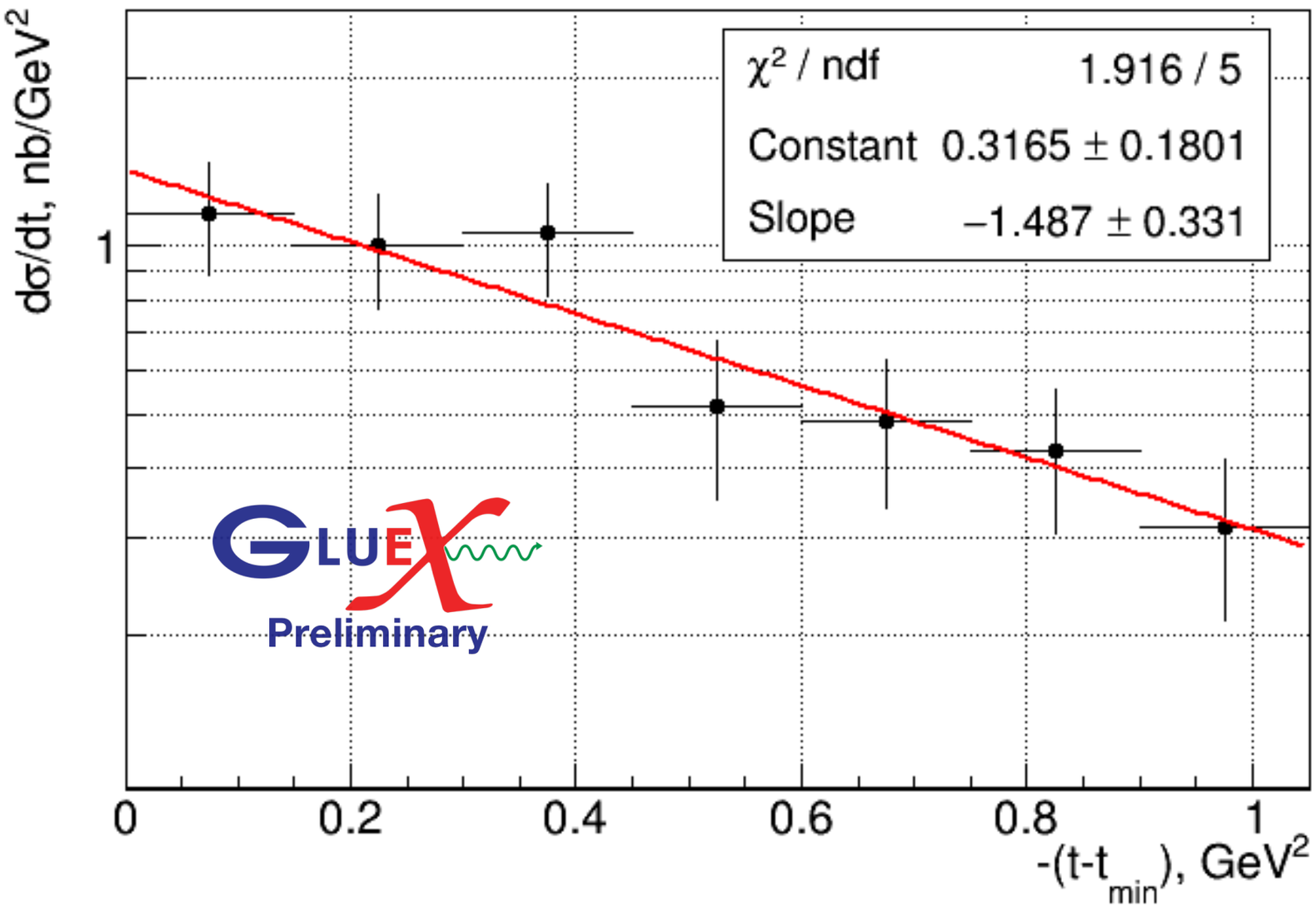


- Zc(3900) production threshold just above energies accessible at GlueX—need CEBAF energy upgrade or EIC

J/ψ @ GlueX: Background Rejection



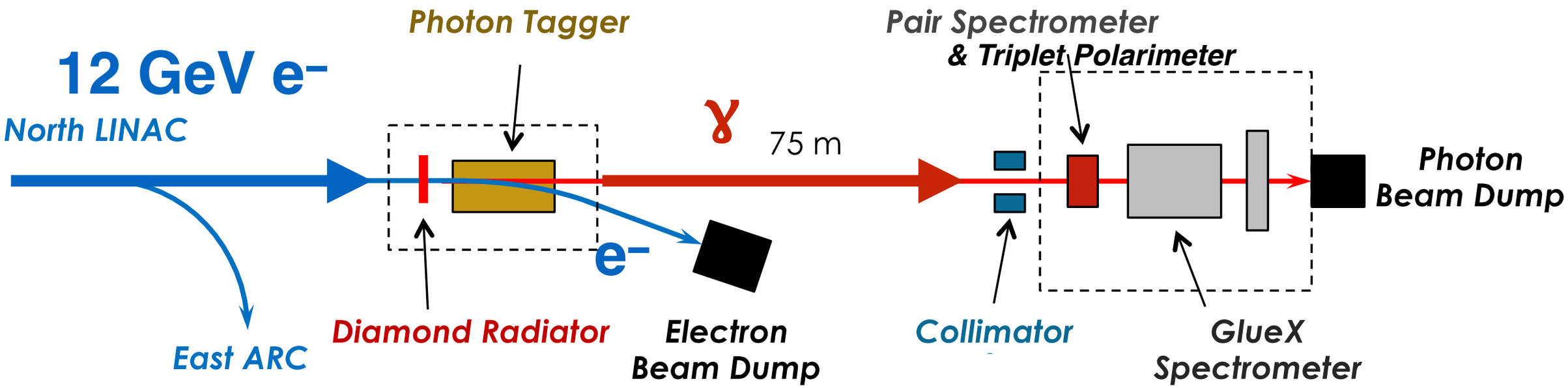
J/ψ @ GlueX: t-slope



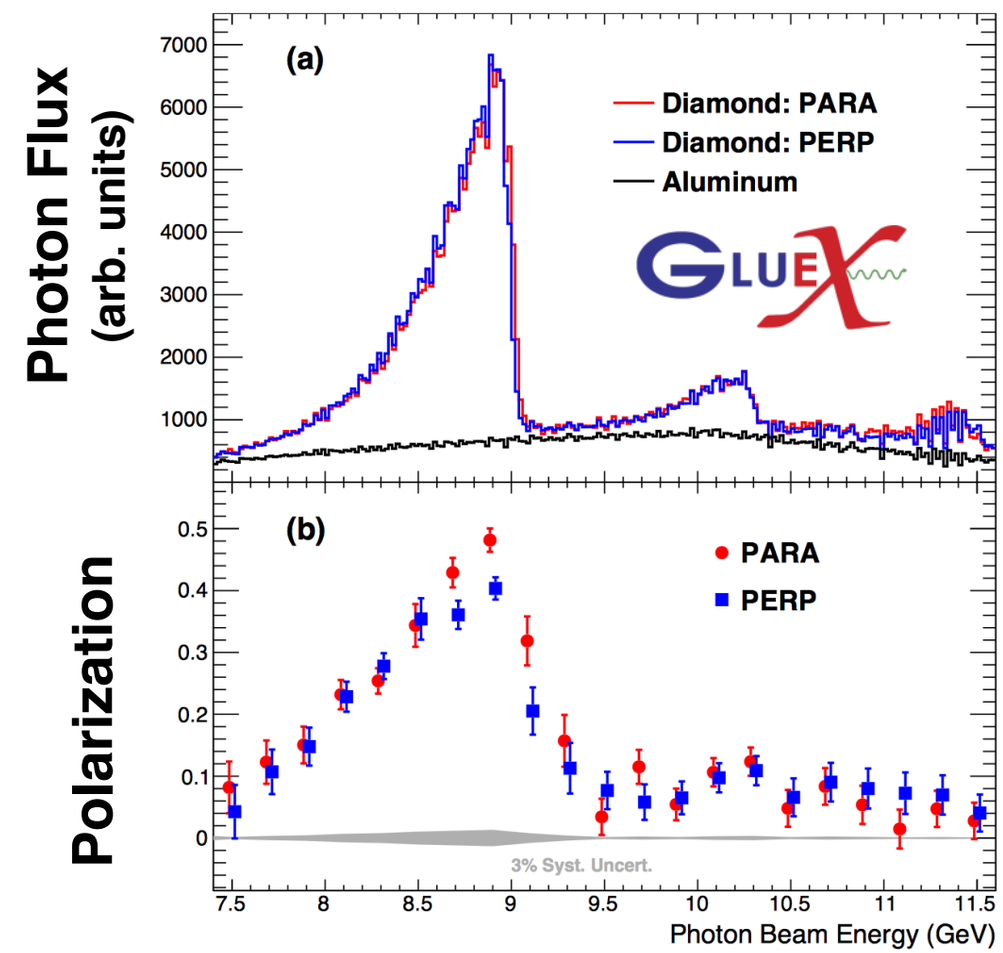
Measurements near threshold

- Cornell at ~11 GeV
  1.25 ± 0.20 GeV^{-2}
- **GlueX at 10–11.8 GeV**
  1.49 ± 0.33 GeV^{-2}
- SLAC at 19 GeV
  2.9 ± 0.3 GeV^{-2}

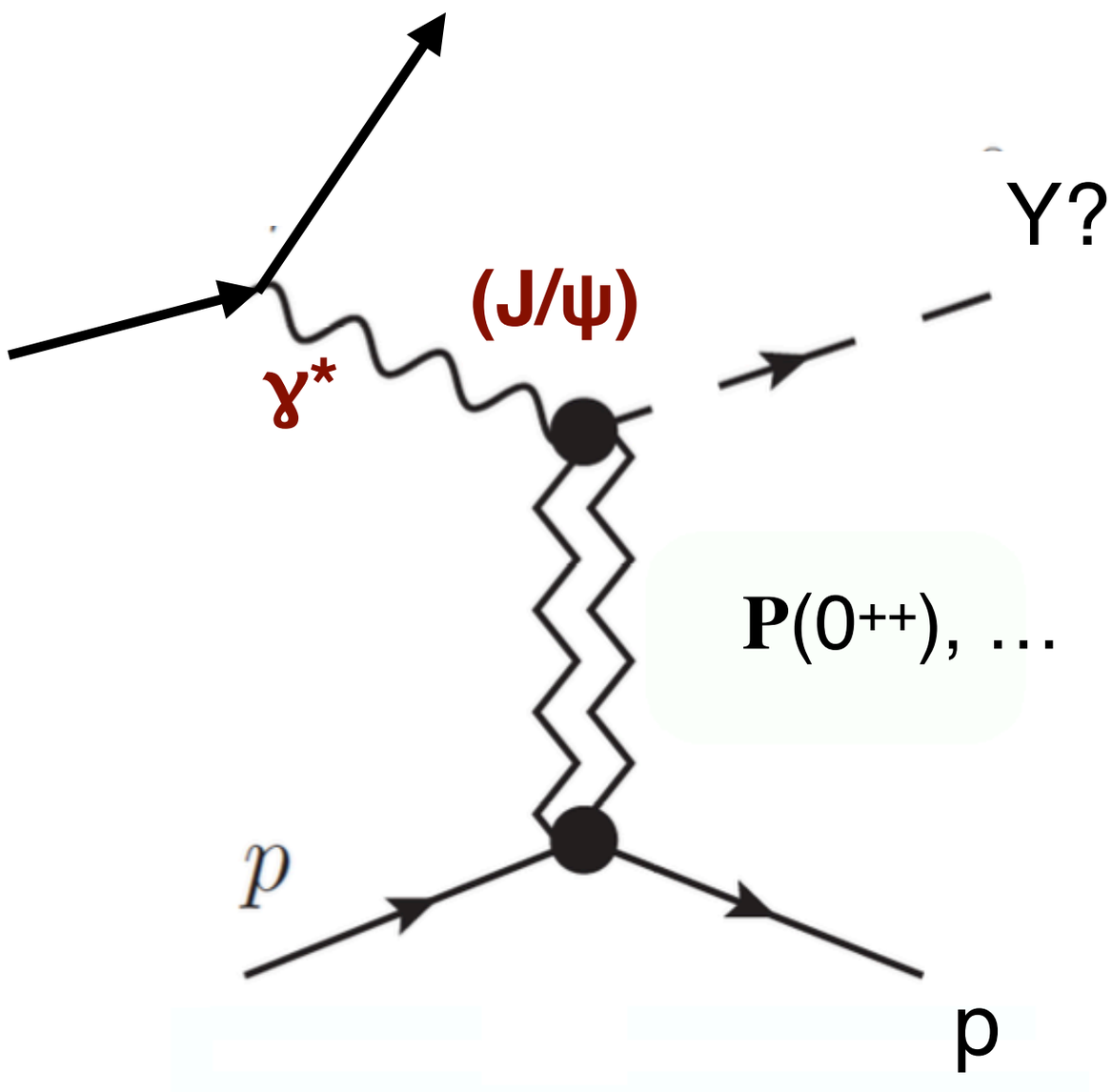
The GlueX Experiment: Photon Beam



- Photon beam generated via coherent bremsstrahlung off thin diamond radiator
- Photon energies tagged by scattered electrons
  - Energy measurement precision < 25 MeV
- Photon linear polarization $P_\gamma \sim 40\%$ in peak
- Intensity of ~1–5 × 10^7 γ/s in peak



Searching for "Charming" Hybrids



- Hybrid mesons should have charm-quark counterparts
  - Candidates exist
  - (Polarized) photons give clean probe
  - Vector mesons should be well produced via VMD
  - Other QN mesons can be produced as well
- EIC gives required CM energy (and luminosity?) to search for these

The GlueX Experiment in Hall D @ JLab

- The GlueX experiment is located in Hall D, newly constructed as part of the Jefferson Lab 12 GeV upgrade.
  - Large acceptance solenoidal spectrometer
  - Linearly polarized photon beam peaking at 9 GeV
  - Detects all decay products from full hadronic photoproduction rate
- 100+ Collaborators from 26 institutions