J/ψ Photoproduction Near Threshold

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Outline of the talk

1. Motivation
2. Description of the Experiment
3. Tagged Analysis Framework
4. Current and Future Work
5. Conclusion

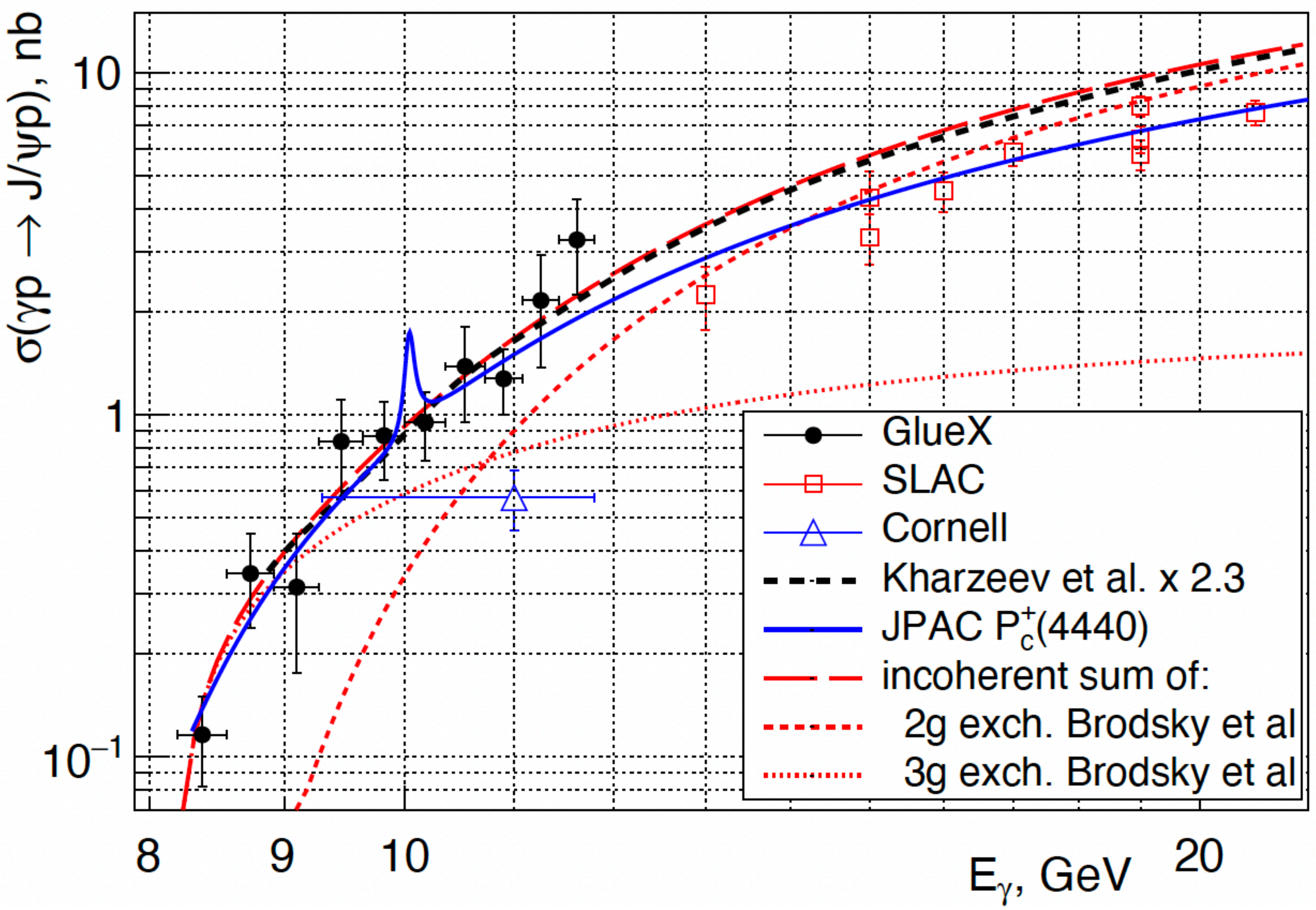
J/ψ photoproduction near threshold

- The production process of the J/ψ meson is sensitive to gluonic form factors that describe the distribution of color charge in the proton

- Near threshold, $E_\gamma > 11$ GeV, the momentum transfer is large and all valence quarks must act coherently, exchanging energy in the form of gluons.

- We can relate the J/ψ photoproduction cross-section to the elastic J/ψ-Nucleon scattering via the Vector Meson Dominance (VMD) model.

- In the VMD model the photon fluctuates to a $q\bar{q}$ pair that scatters off the nucleon and forms the outgoing vector meson



GlueX Published Cross Sections of J/psi Photoproduction.

$$\frac{d\sigma_{\gamma N \to VN}}{dt} = \kappa \frac{3\Gamma(V \to e^+e^-)}{\alpha m_V} \frac{d\sigma_{VN \to VN}}{dt}$$

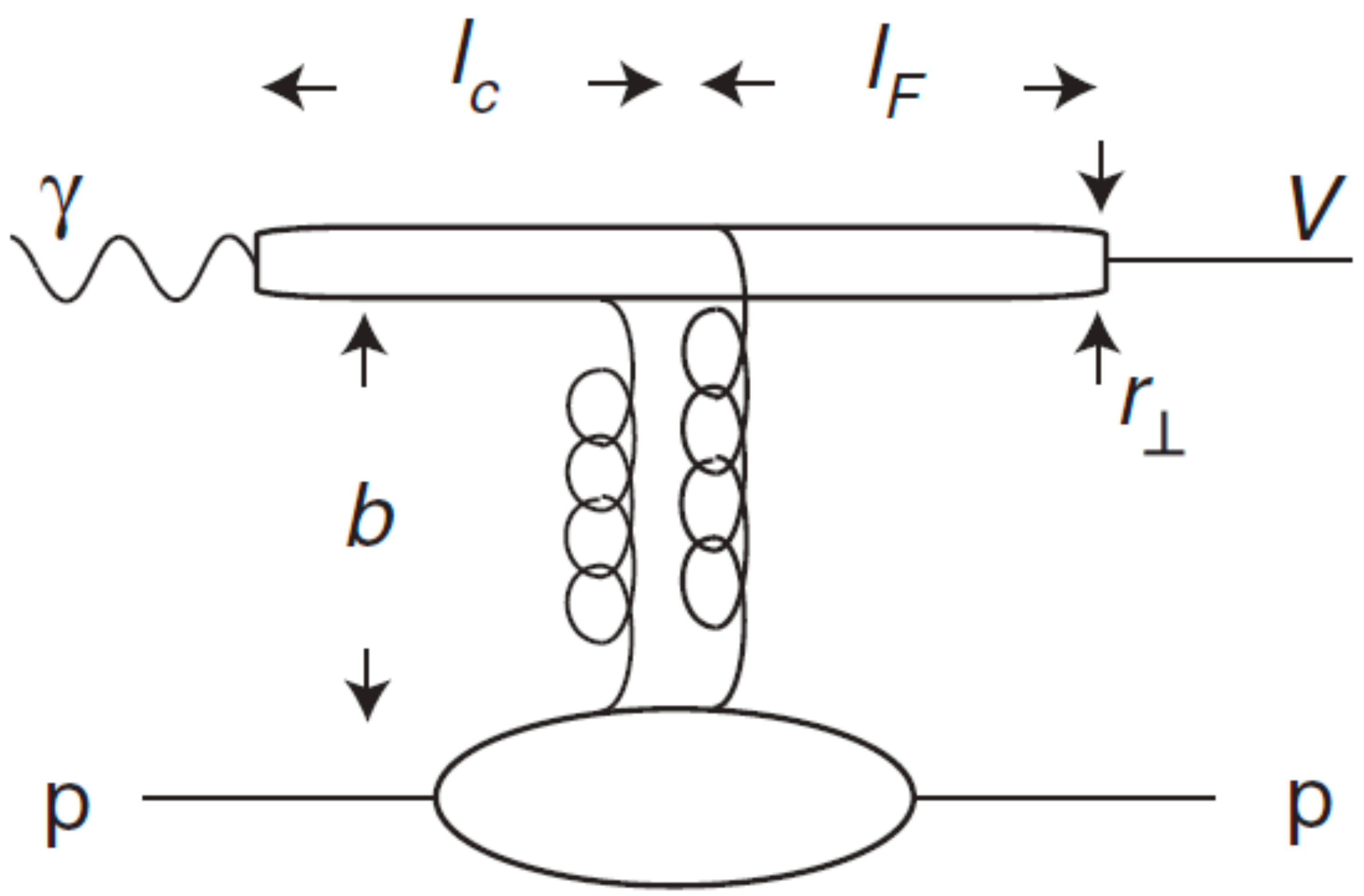
$$\sigma_{VN \to \psi N} = \left(\frac{4\pi\alpha}{\gamma_\psi^2}\right) \sigma_{el}^{\psi N}$$

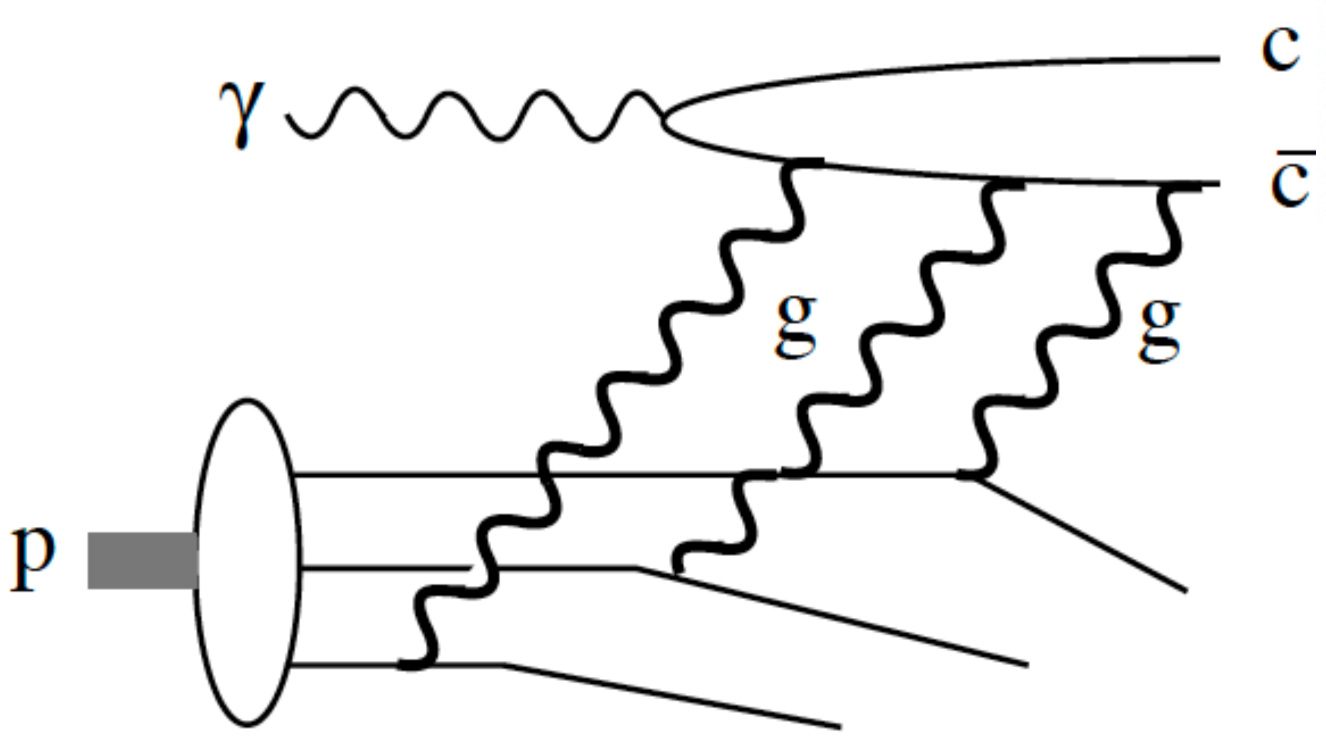
A. Ali, et. al. (GlueX Collaboration), Phys. Rev. Lett. 123, 072001 (2019)

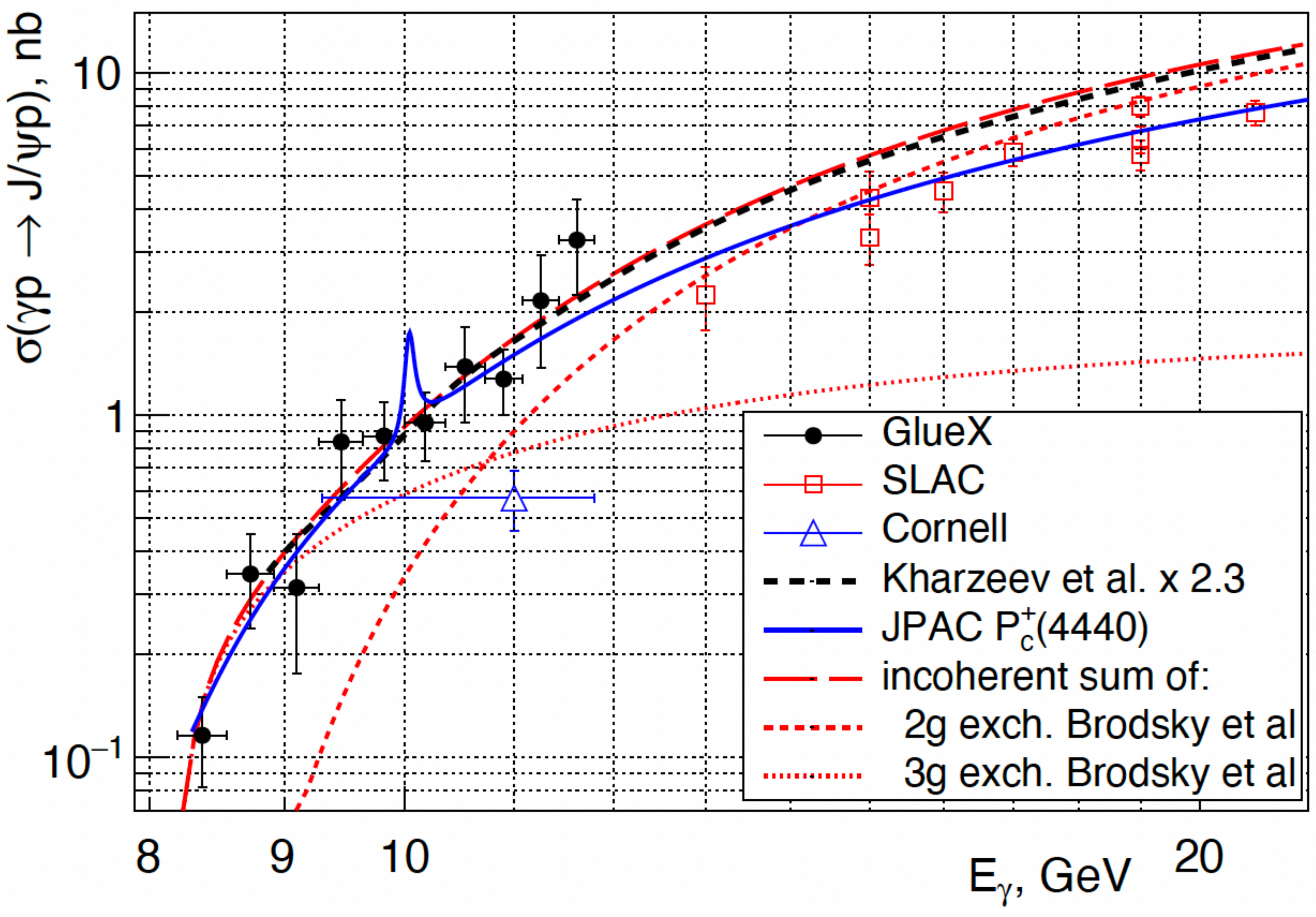
Proposed Models for J/ψ photoproduction

- There are three processes that contribute to the cross-section and define the mechanism of J/ψ photoproduction in relation to the interaction of quarks and gluons in the proton.

- At threshold the 2- and 3- gluon exchanges, are the ones expected to dominate.







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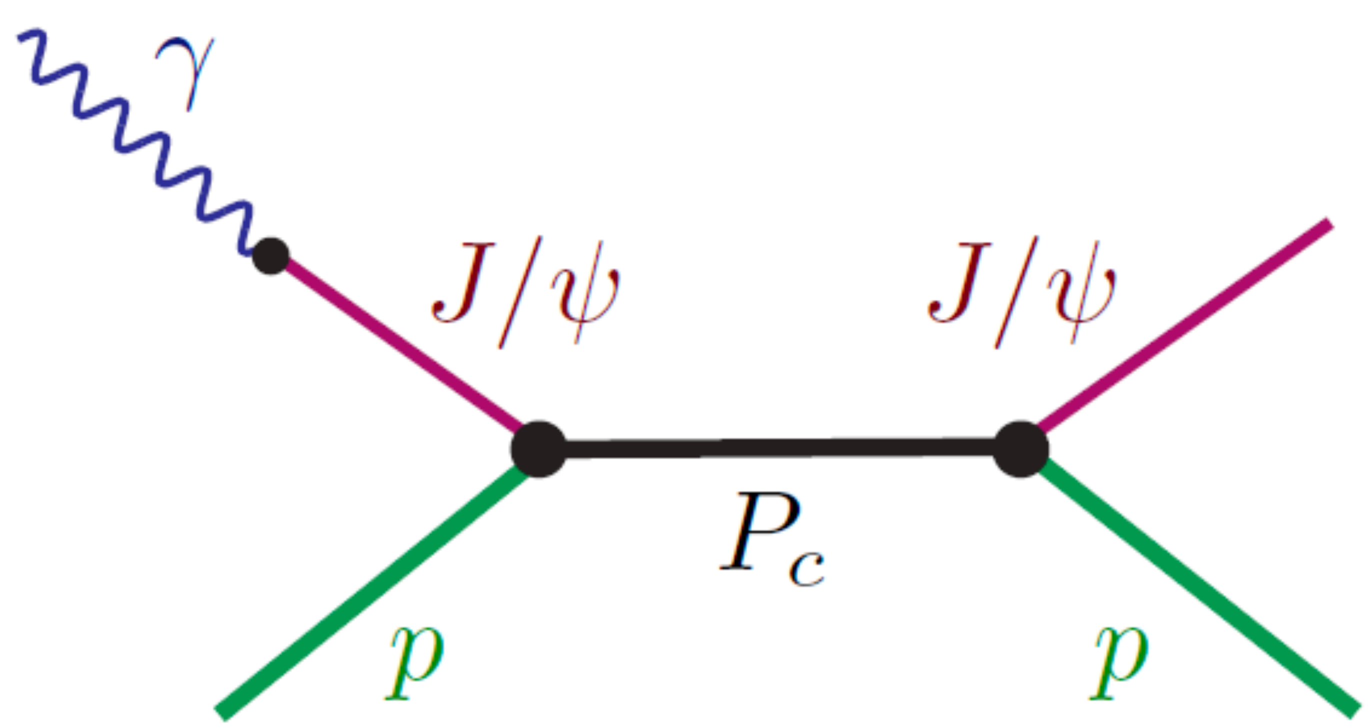
A. Ali, et. al. (GlueX Collaboration), Phys. Rev. Lett. 123, 072001 (2019)
S. Brodsky, E. Chudakov, P. Hoyer, J. Laget, Phys. Lett. B. 498, 23 (2001)

Pentaquark states P_c

- The LHCb collaboration reported that the $P_c(4450)^+$ structure in the decay channel $P_c^+ \to J/\psi p$, consist on two narrow overlapping peaks $P_c(4440)^+$ and $P_c(4457)^+$ at 4440 and 4457 MeV respectively

- It is expected that these states can be produced in the s-channel through the photoproduction process $\gamma + p \to P_c \to J/\psi + p$

- The calculation of the yield of this process will be useful for detailed studies of the production of pentaquark resonances.



$$\sigma(\gamma + p \to P_c \to J/\psi + p) = \frac{2J+1}{4} Br(P_c \to \gamma + p) Br(P_c \to J/\psi + p) 1.1 \times 10^{-27} \text{cm}^2$$

R. Aaij et al. Phys. Rev. Lett., 122,22, (2019).
V. Kubarovsky and M. B. Voloshin, Phys. Rev. D ., 92, 031502,R , (2015).

The experiment

- For this analysis the RG-A Fall 2018 and Spring 2019 Pass1 data is presented.
  - Fall 2018: Inbending and Outbending configurations, 10.6 GeV
  - Spring 2019: Inbending configuration, 10.2 GeV

Tagged Analysis Reaction

The reaction to study is

$$ep \to e'J/\psi\ p' \to e'e^+e^-X$$

- Where e^+ and e^- are measured in the Forward Detector, e' is measured in the Forward Tagger and X corresponds to the recoil proton and will be identified in the missing momentum analysis.

- We have other two topologies that we can explore:

$$ep \to e'e^-p'X$$
$$ep \to e'e^+p'X$$

Tagged Analysis Framework

$ep \to e'J/\psi\ p' \to e'e^+e^-(p')$

Analysis cuts

- Electron e^-
  1. $p > 1.95$ GeV/c
  2. $E_{PCAL} > 0.07$ GeV
  3. $V_{PCAL} > 9$ cm
  4. $W_{PCAL} > 9$ cm
  5. $-8 < V_z < 4$ cm

- Positron e^+
  1. $p > 1.95$ GeV/c
  2. $E_{PCAL} > 0.07$ GeV
  3. $V_{PCAL} > 9$ cm
  4. $W_{PCAL} > 9$ cm
  5. $SF_{EC} \geq (0.195 - SF_{PCAL})$

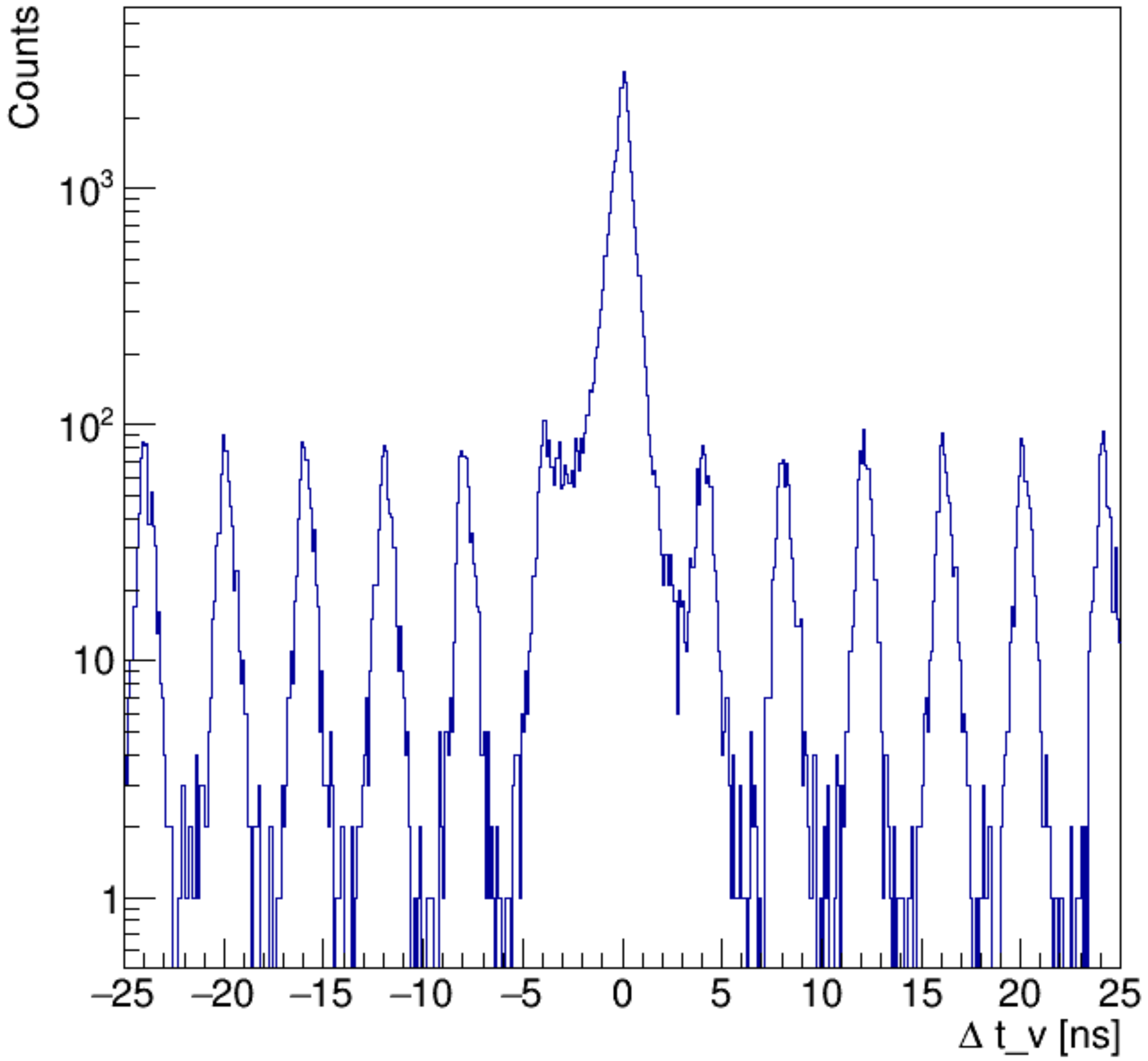
- Events with vertex time difference $|v_{t_{e^-}} - v_{t_{e^+}}| \leq 1$ were accepted
- Radiative photons with θ coincidence with $|\Delta\theta| < 0.7$ for energy loss correction

Tagged Analysis Framework

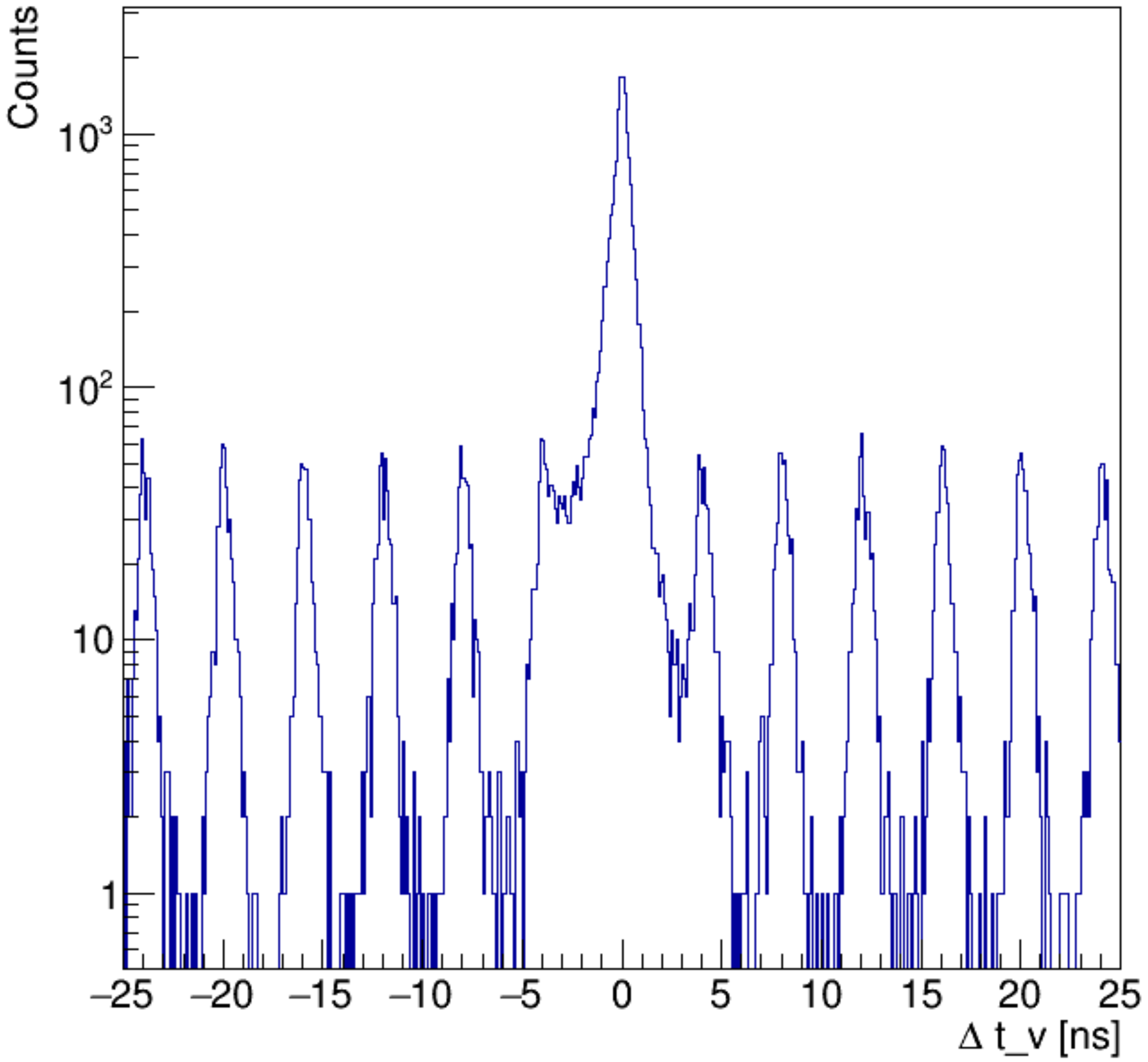
$ep \to e' J/\psi \ p' \to e' e^+ e^- (p')$

Selection of J/ψ events

- Events that contain one electron in the Forward Tagger and have $|\Delta t_\nu| < 2$ ns are selected



Fall 2018



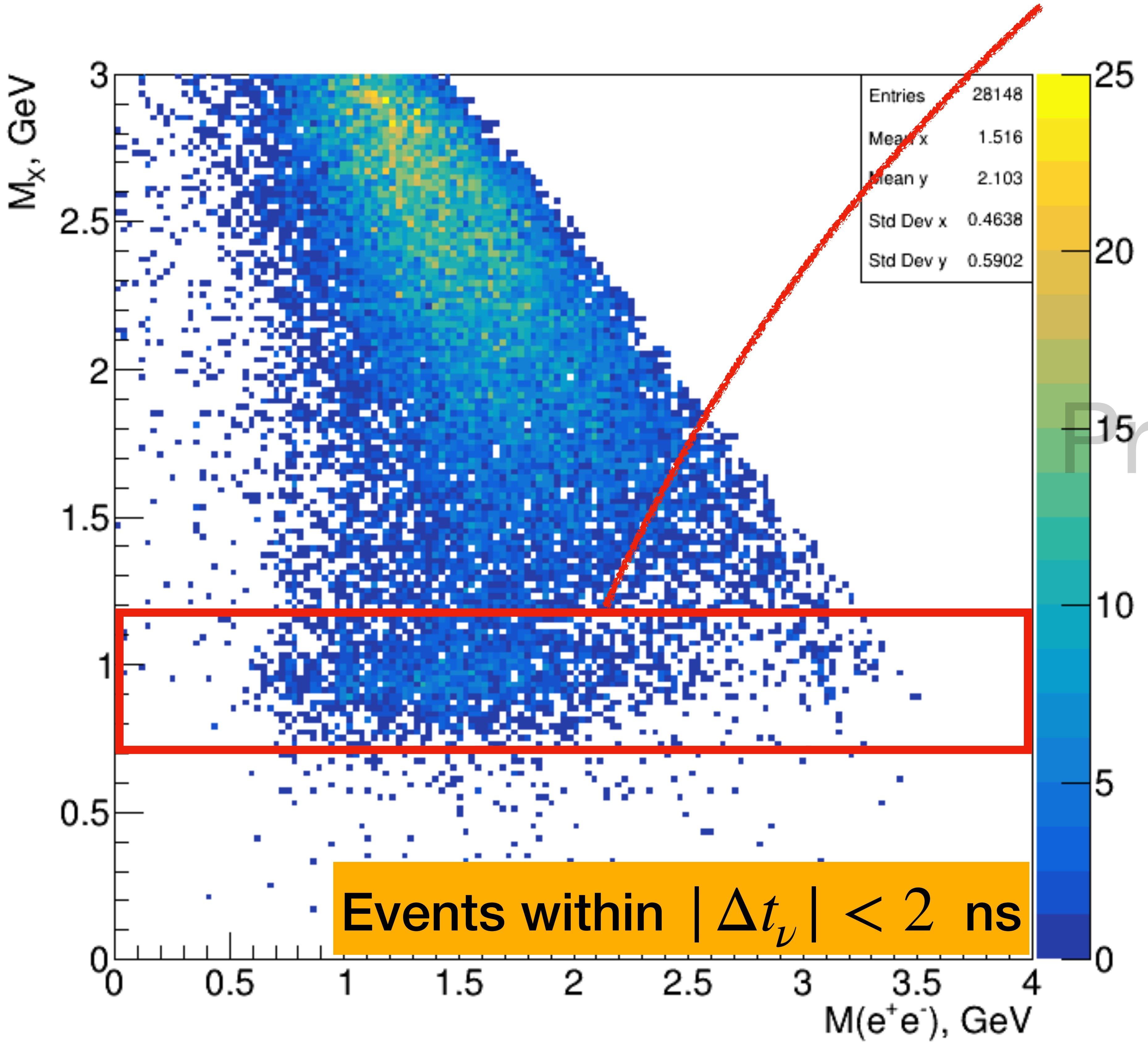
Spring 2019

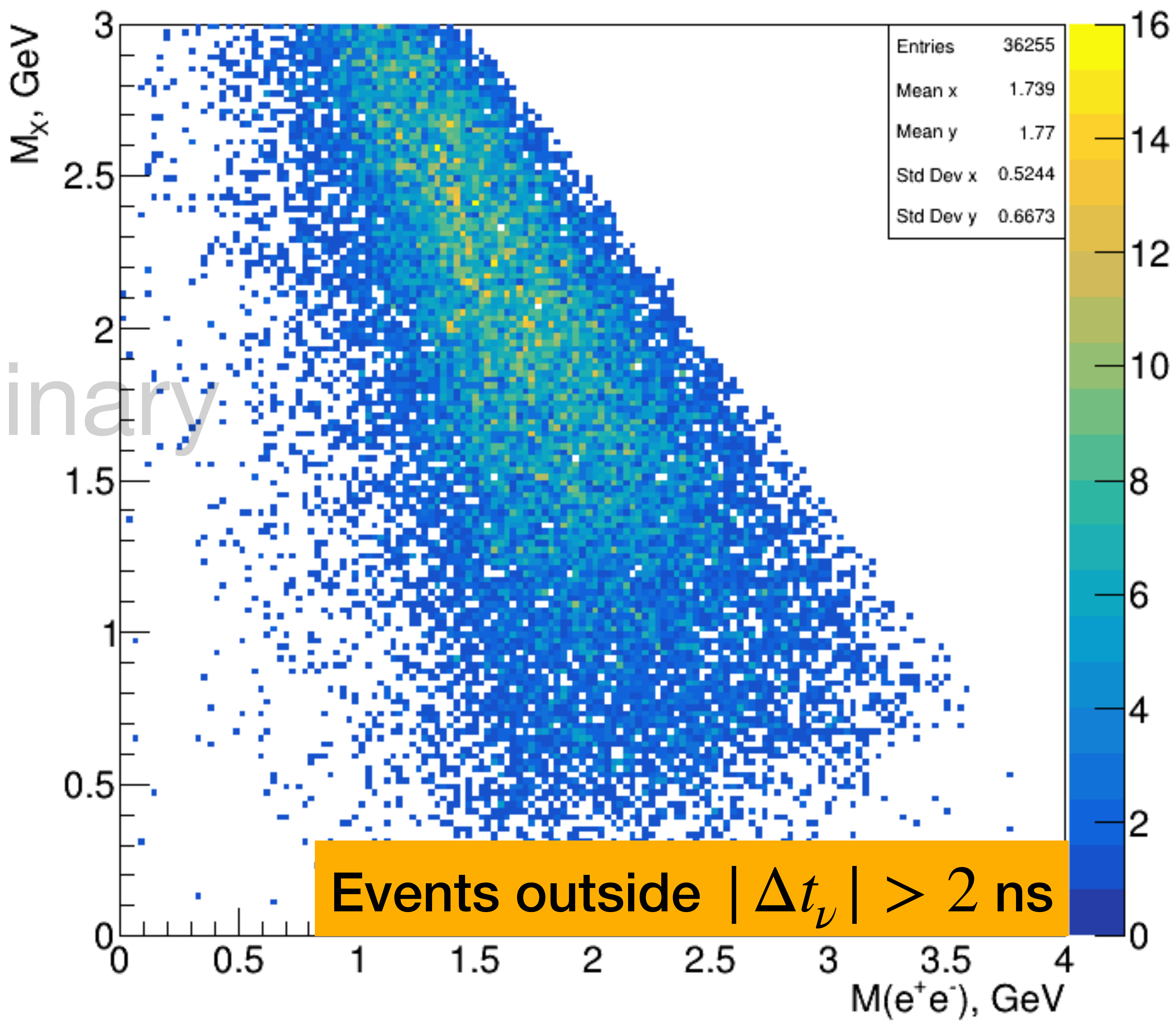
Tagged Analysis Framework

$ep \rightarrow e'J/\psi\ p' \rightarrow e'e^+e^-(p')$

Selection of J/ψ events - Missing momentum analysis

- The missing four-momentum is defined as $p_X = p_e + p_p - p_{e^-} - p_{e^+} - p_{e'}$
- Events with a missing mass between 0.7 GeV and 1.2 GeV are selected for the final analysis.



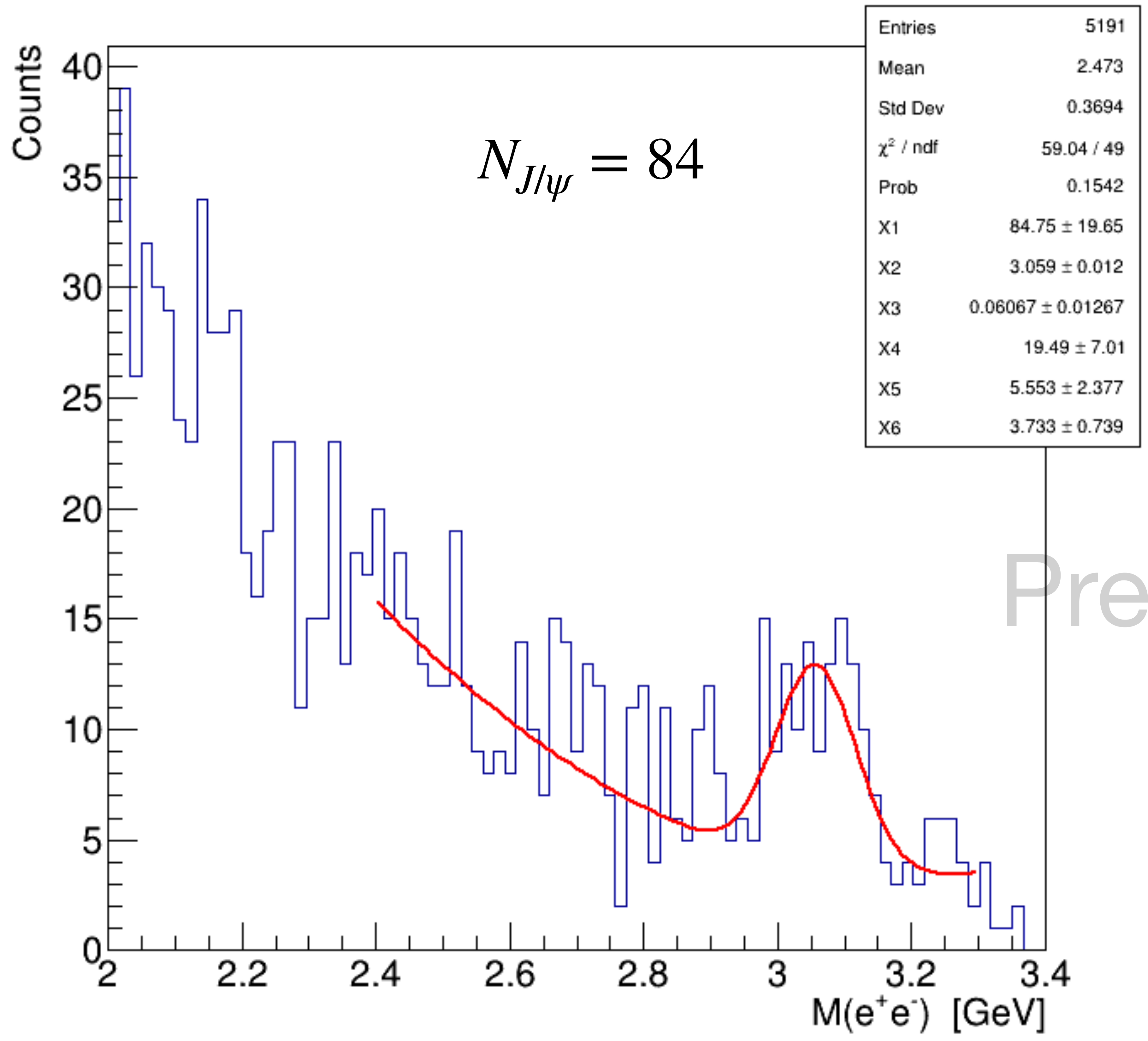


Tagged Analysis

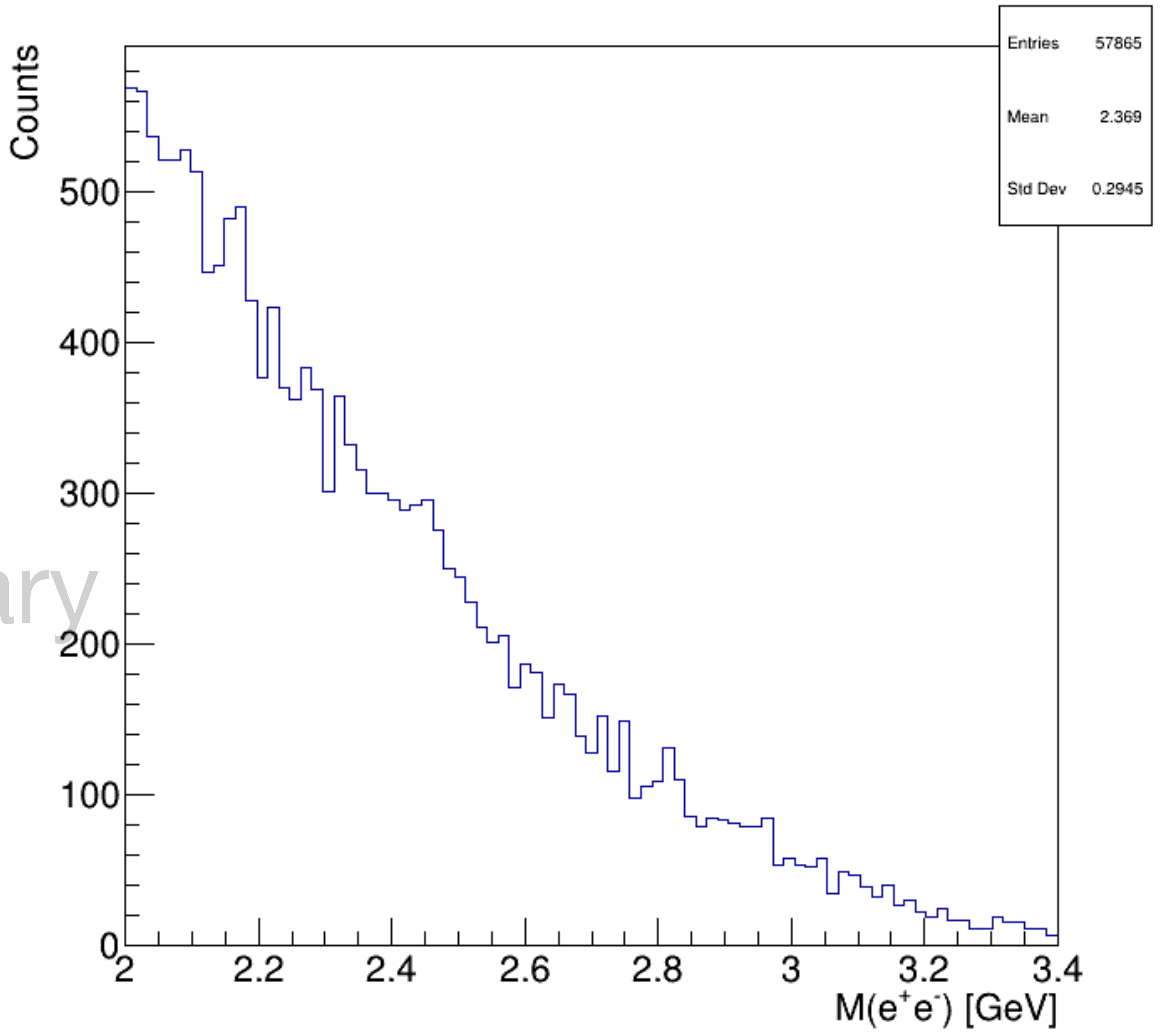
J/ψ events

$ep \to e'J/\psi\ p' \to e'e^+e^-(p')$

$M^2(e^-e^+) = (p_{e^-} + p_{e^+})^2$



Events within $|\Delta t_\nu| < 2$ ns

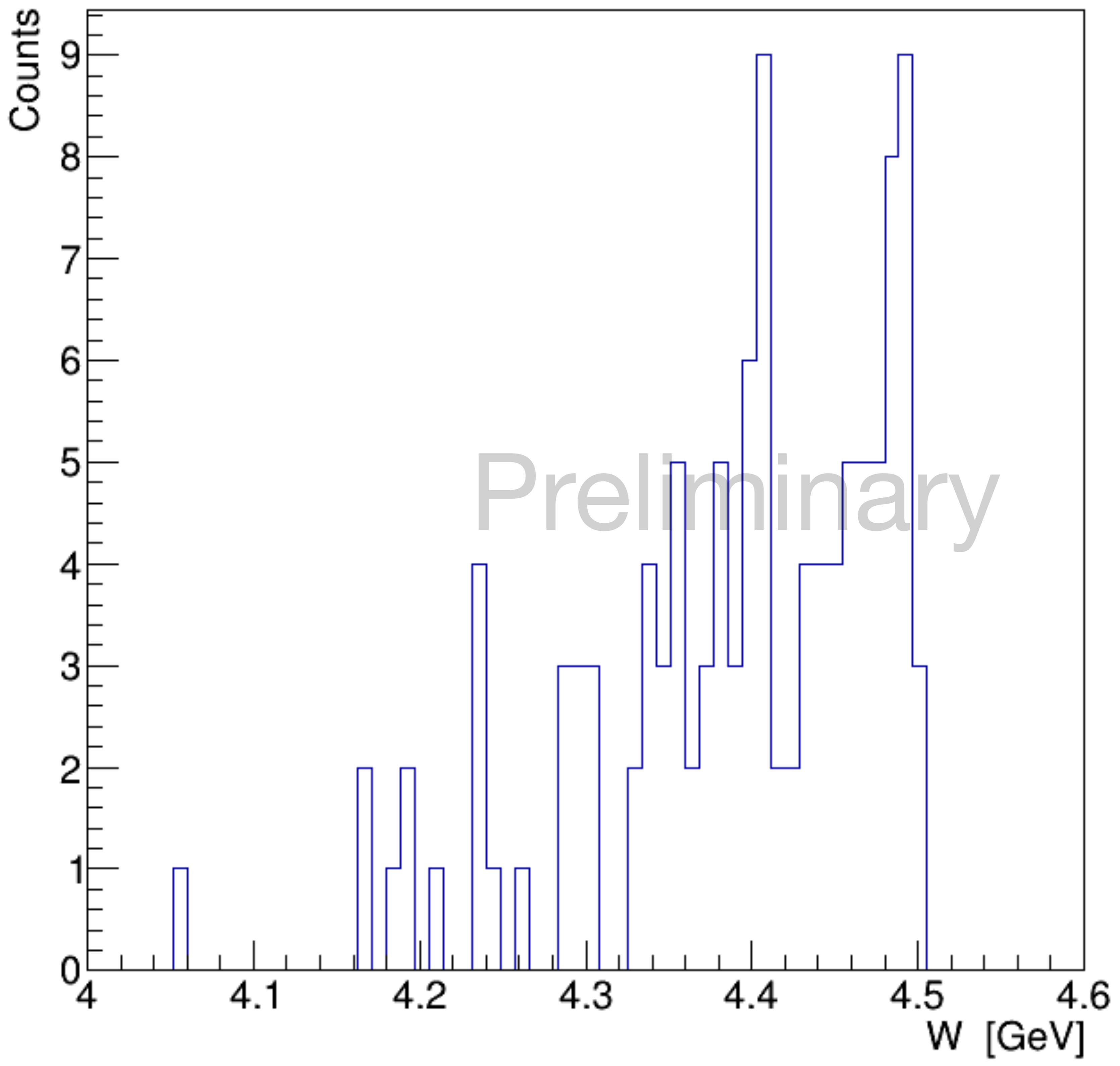


Events outside $|\Delta t_\nu| > 2$ ns

Tagged Analysis

Hadronic Mass

$$ep \to e'J/\psi\ p' \to e'e^+e^-(p')$$



- For this distribution, we consider events that fall into the mass range $3.0 < M(e^+e^-) < 3.2$ GeV
- The hadronic mass corresponds to the mass of the pentaquark P_c . We expect to see their existence in this distribution.
- The next phase of the analysis is to define the W-binning, taking into account the two different beam energies of the data sets, to construct the hadronic mass distribution.

$$W = \sqrt{m_p^2 + 2m_pE_\gamma - Q^2}$$

$$E_\gamma = E_{beam} - E_{e'} \qquad Q^2 = 2E_{beam}E_{e'}(1 - \cos(\theta_{e'}))$$

Next Steps

Extraction of cross-section

- The cross-section depends on the total center of mass energy, W, the exchange photon virtuality Q^2 and the transfered momentum squared, t

$$\frac{d\sigma}{dWdQ^2dt} = \frac{N_{J/\psi}(W, Q^2, t)}{L \cdot Br \cdot \eta} \frac{1}{\Delta W \Delta Q^2 \Delta t}$$

- Where $L = N_e \cdot N_p$, $Br = 0.06$ and η is the detector efficiency.

- When we have low statistics, the width of the kinematic variables $(\Delta W, \Delta Q^2, \Delta t)$ becomes large and the dependencies are limited to one variable by integrating over the others.

$$\frac{d\sigma_i}{dW} = \frac{Y_i}{L \cdot Br} \frac{1}{\Delta W} \qquad Y_i = \sum_{j=1}^{N^i_{J/\psi}} \frac{1}{\eta_j}$$

- Finally, we can explore the other two topologies that are complementary to the reaction presented here and would represent an increase in acceptance.

Thank you!