Analysis of J/ ψ photoproduction near threshold

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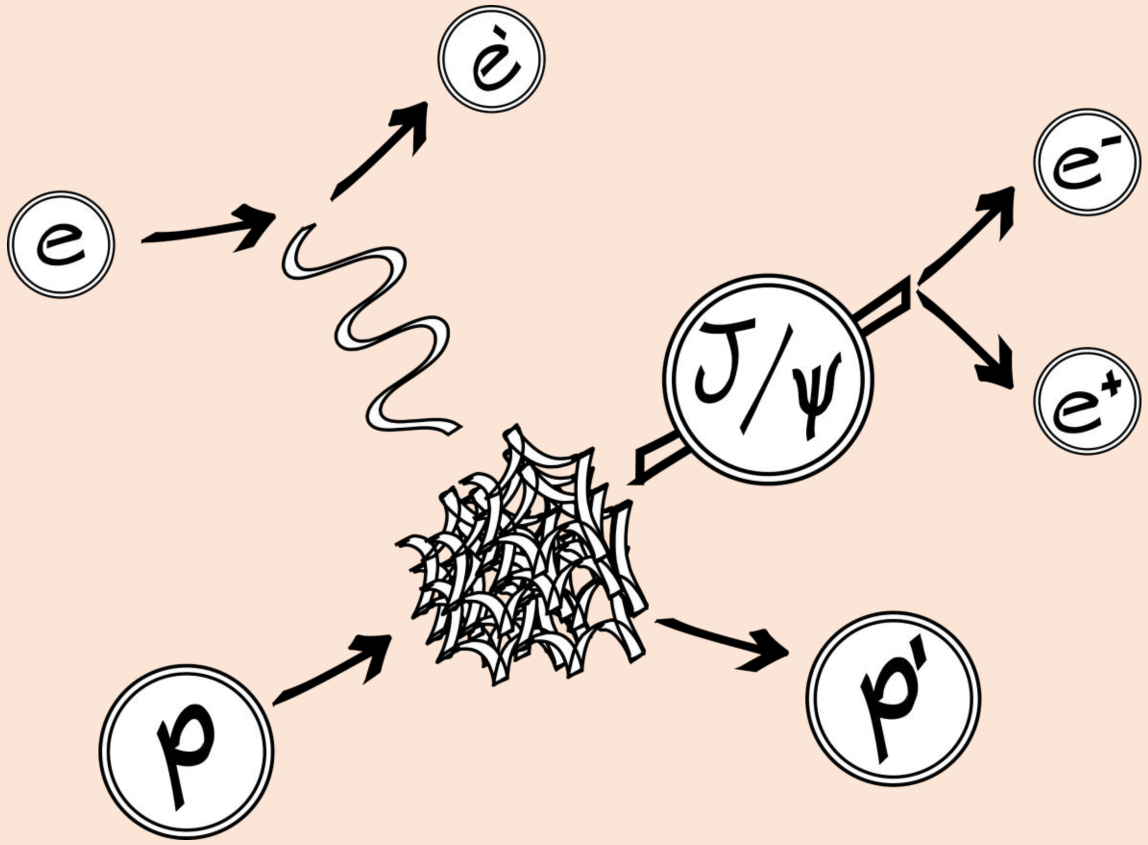
Motivation

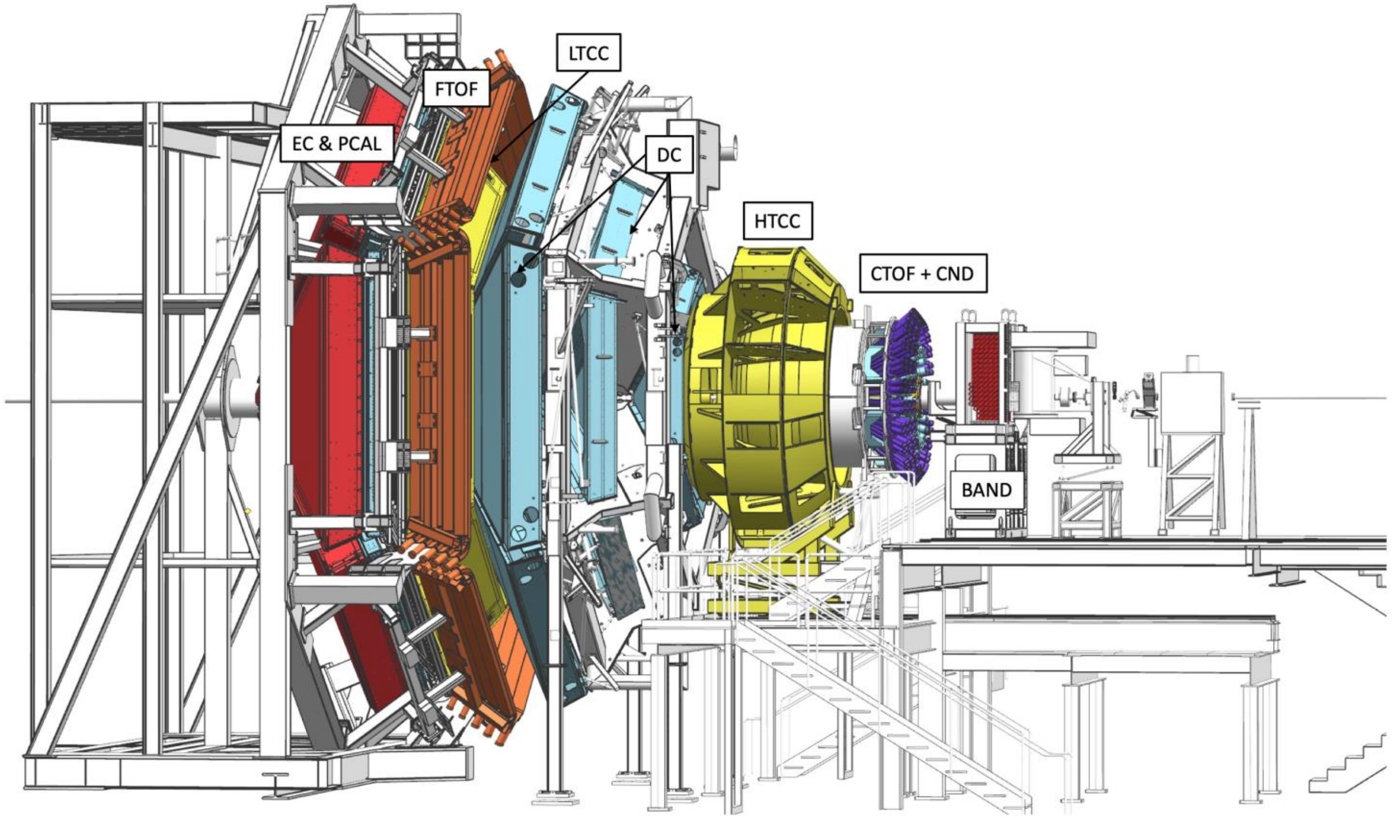
- The production process of the J/ψ is sensitive to gluonic form factors
    - Such functions describe the distribution of color charge in the proton.
- Near threshold, the momentum transfer is large and all valence quarks must act coherently, exchanging energy in the form of gluons.
- We can relate the cross sections to the form factors.



*S.J. Brodsky, et al. (2008)
*CLAS12 Collaboration (2012).

Experiment

The experiment takes place in Hall B at JLab. The CLAS12 detector is capable of detecting and identifying J/ψ mesons



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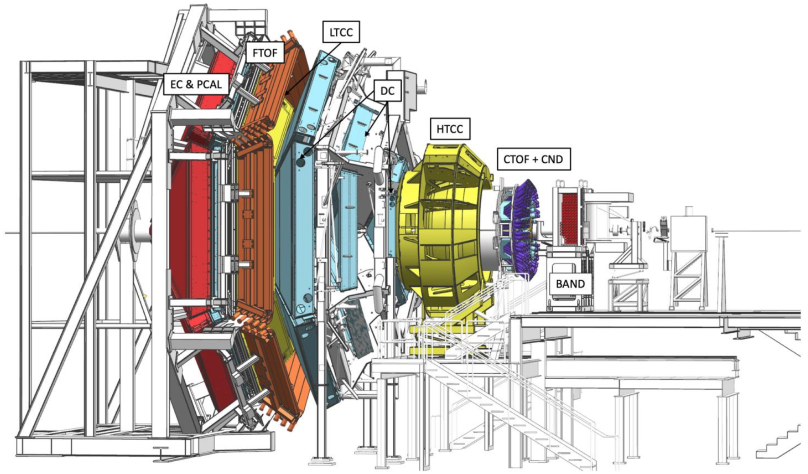
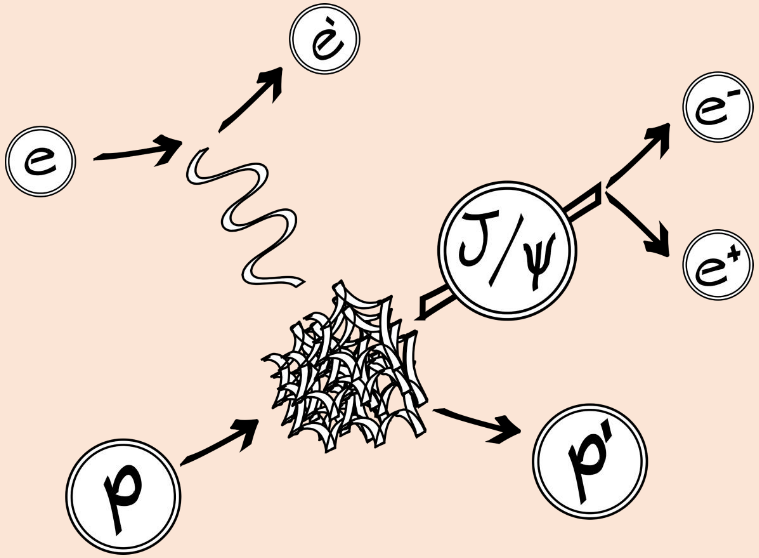
We identify the number of J/ψ mesons using their decay to e^+e^- pairs.





Experiment

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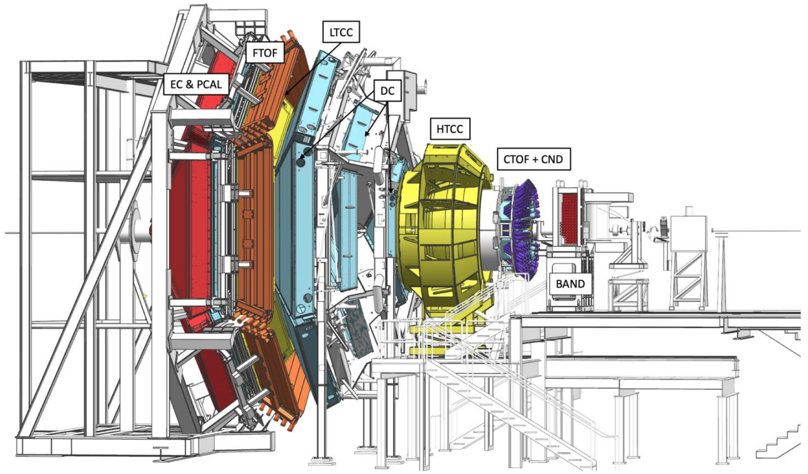
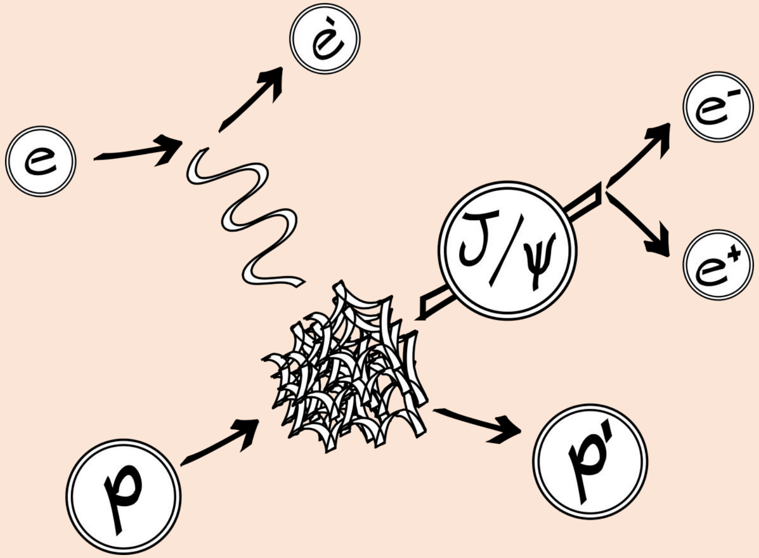
We identify the number of J/ψ mesons using their decay to e^+e^- pairs.

The final step is to calculate the differential and total cross sections.





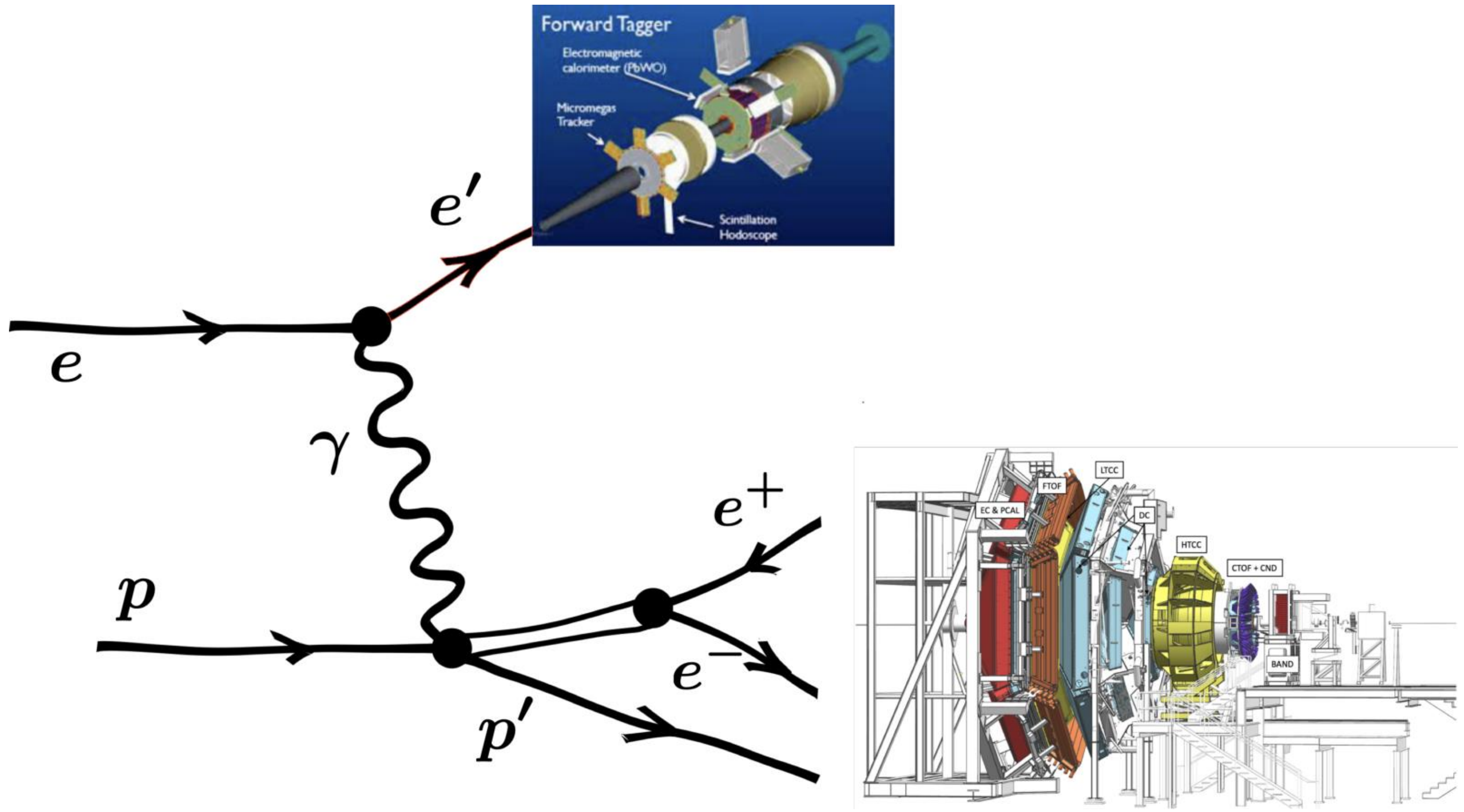
Untagged

$$ep \rightarrow e^+e^-pX$$

Tagged

$$ep \rightarrow e^+e^-e'X$$

e' is measured in the Forward Tagger



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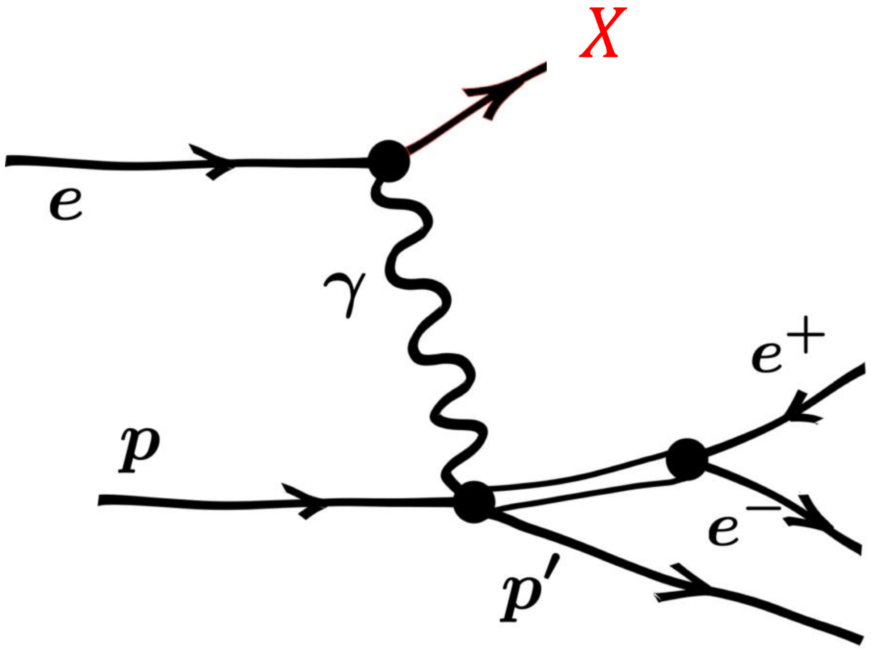

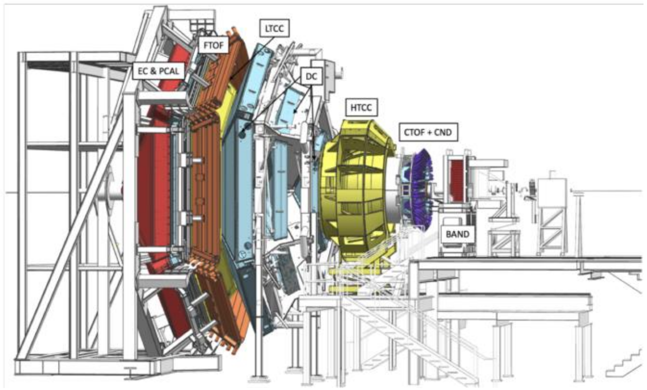

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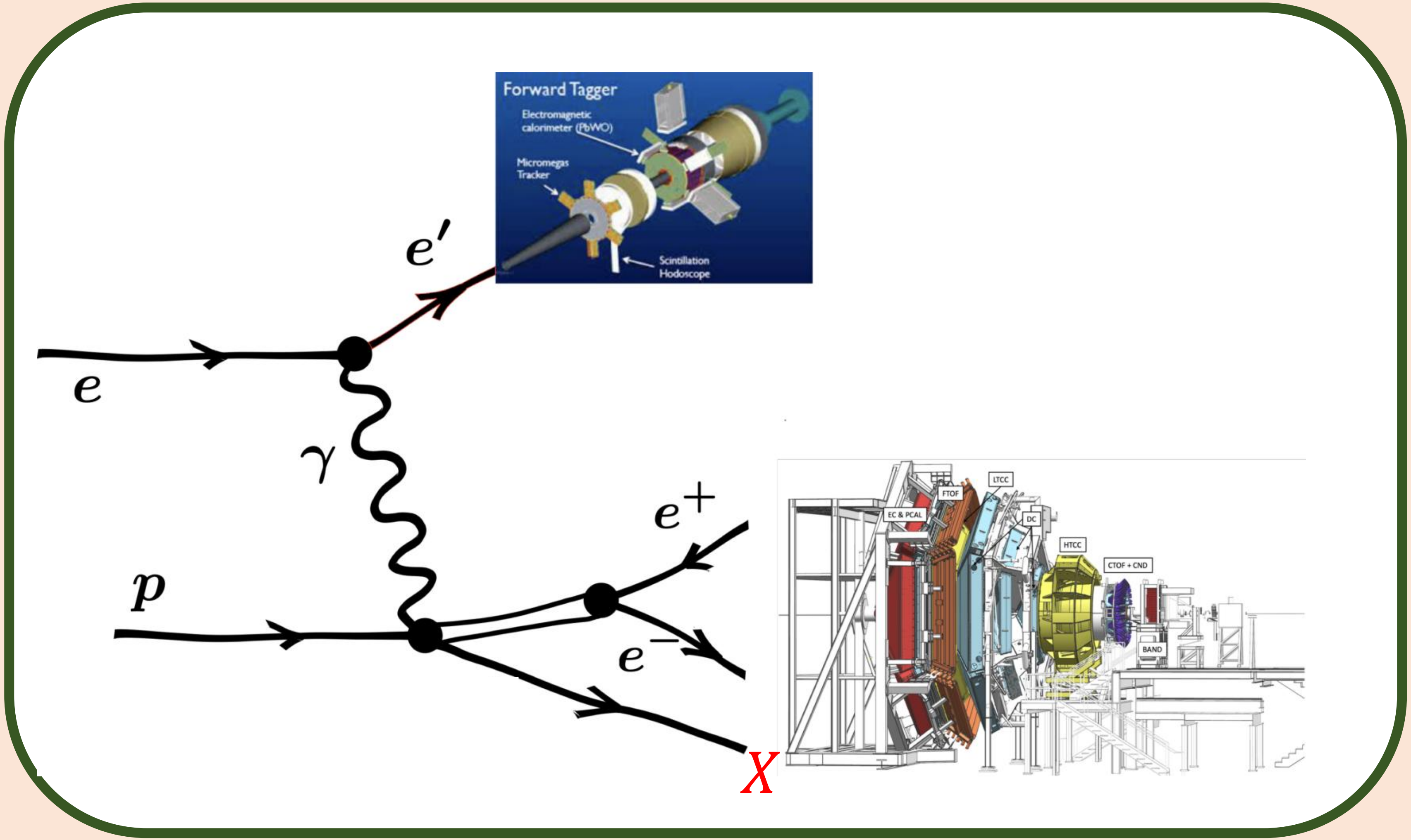


Datasets and post-processing

Dataset	Beam Energy	Torus Polarization
Fall 2018	10.6 GeV	Inbending
		Outbending
Spring 2019	10.2 GeV	Inbending

- Data from the detected particles is processed and organized as output banks.
- The primary banks that are utilized for data analysis are from the CLAS12 Event Builder (EB).
- The EB banks consist of four-vector and vertex information as well as the associated detector hits for each of the charged tracks and neutral tracks.
- We have access to the kinematics of the process.

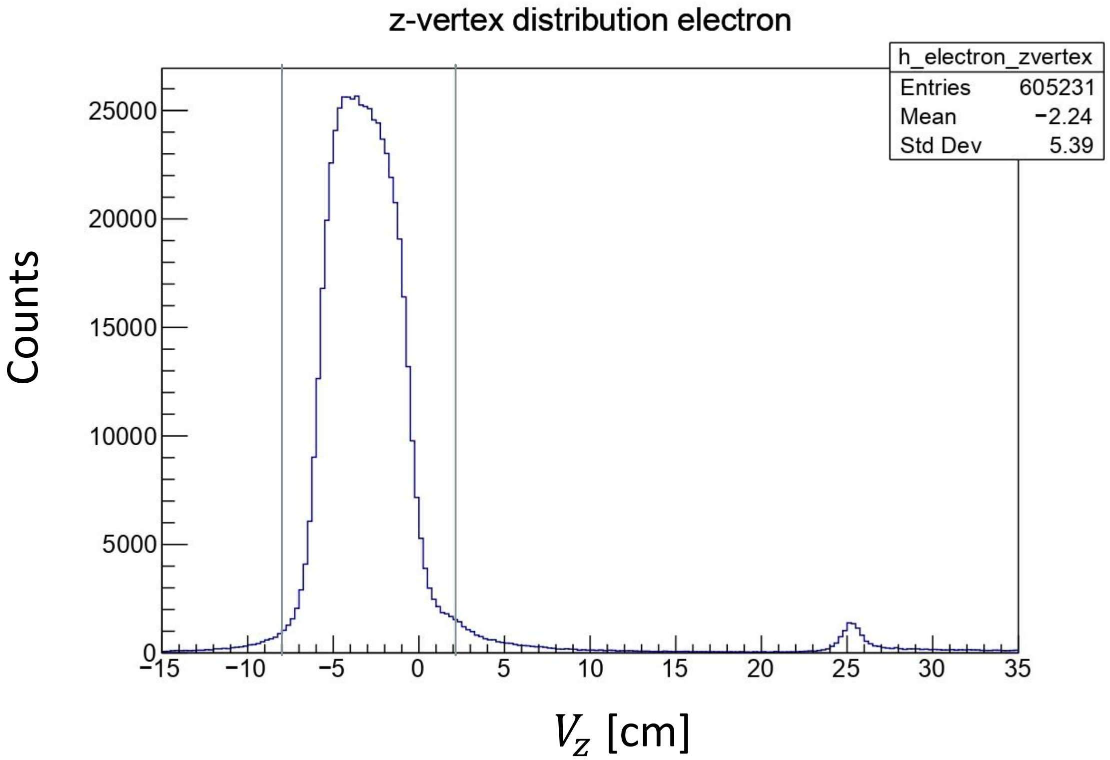
Event Selection e^+e^-

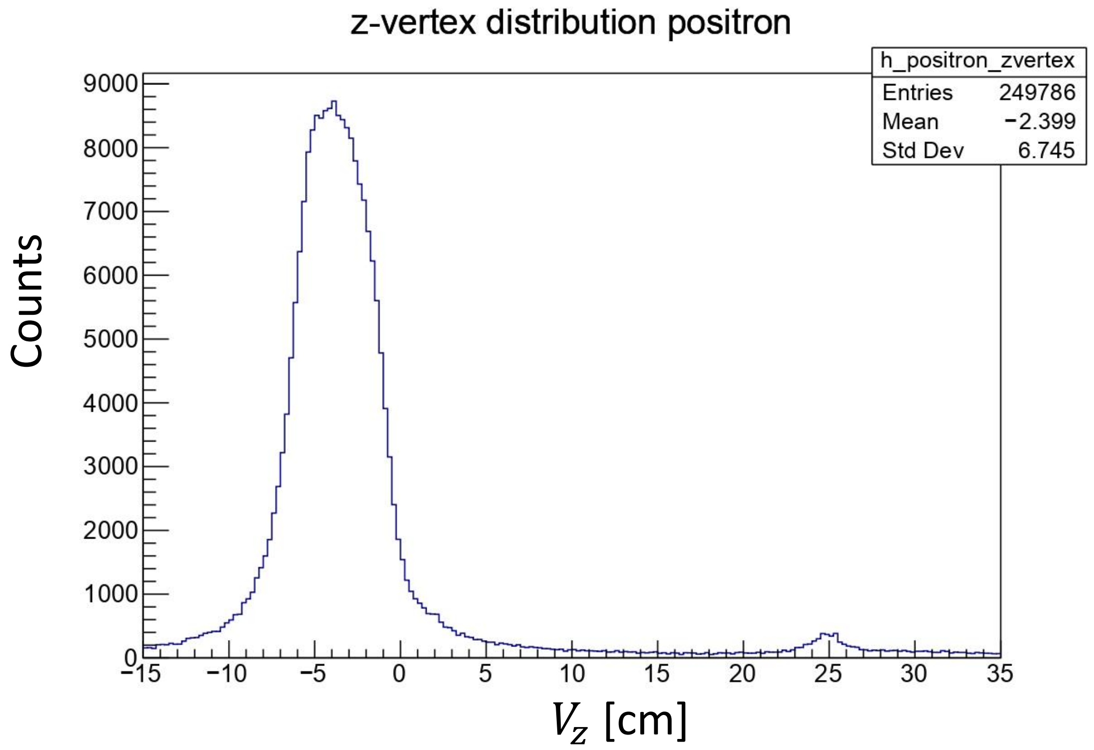
- The e^+e^- pair are reconstructed and identified in the CLAS12 forward detector (FD).
- The number of electrons, positrons, protons, and other charged and neutral particles is counted in the event.
- Events that have only one electron, one positron and no other charged particles are selected for the next step.
- Below the 4.9 GeV/c momentum, the identification of electrons and positrons is effective and less susceptible to pion contamination.

Event Selection e^+e^-

- Cut on the z-vertex distributions. For inbending dataset, electron vertex is used, for the outbending the z-vertex of the positron is used. This is to take into account the difference in the FD tracking vertex reconstruction for different charge tracks.

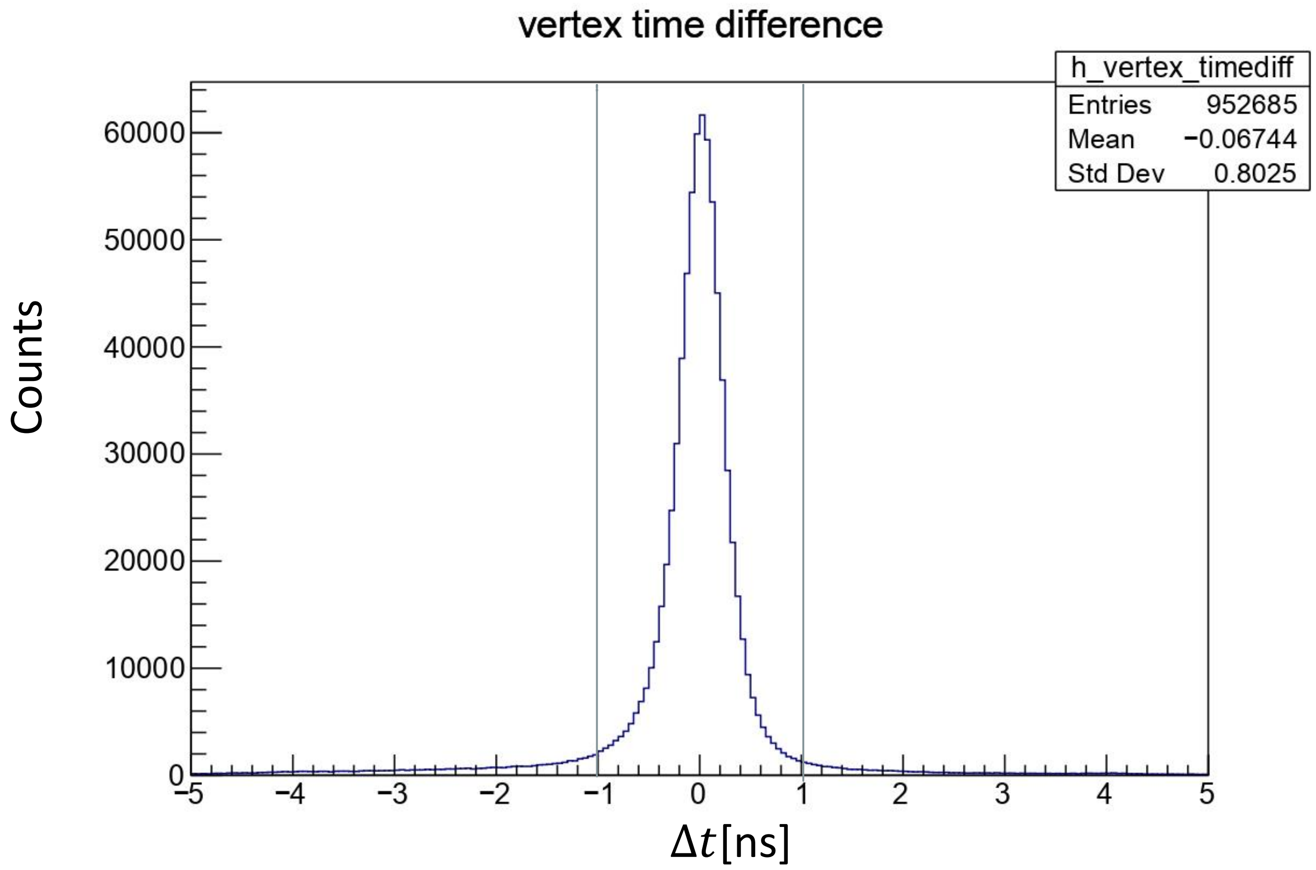
$$-8\ \mathrm{cm} < \mathrm{v_z} < 1\ \mathrm{cm}$$





Event Selection e^+e^-

- Cut on the vertex time difference of the electron and the positron.



Untagged Case $ep \rightarrow e^+e^-pX$

- In addition to the e^+e^- we identify a proton in the Forward Detector.
- We calculate the missing mass and Q^2.

$$M_X^2 = \mathrm{p}_X^2$$

$$Q^2 = 2 \cdot E_{beam} \cdot (P_X - P_X^z)$$

$$\mathrm{p}_X = \mathrm{e} + \mathrm{p} - \mathrm{k}^+ - \mathrm{k}^- - \mathrm{p}'$$

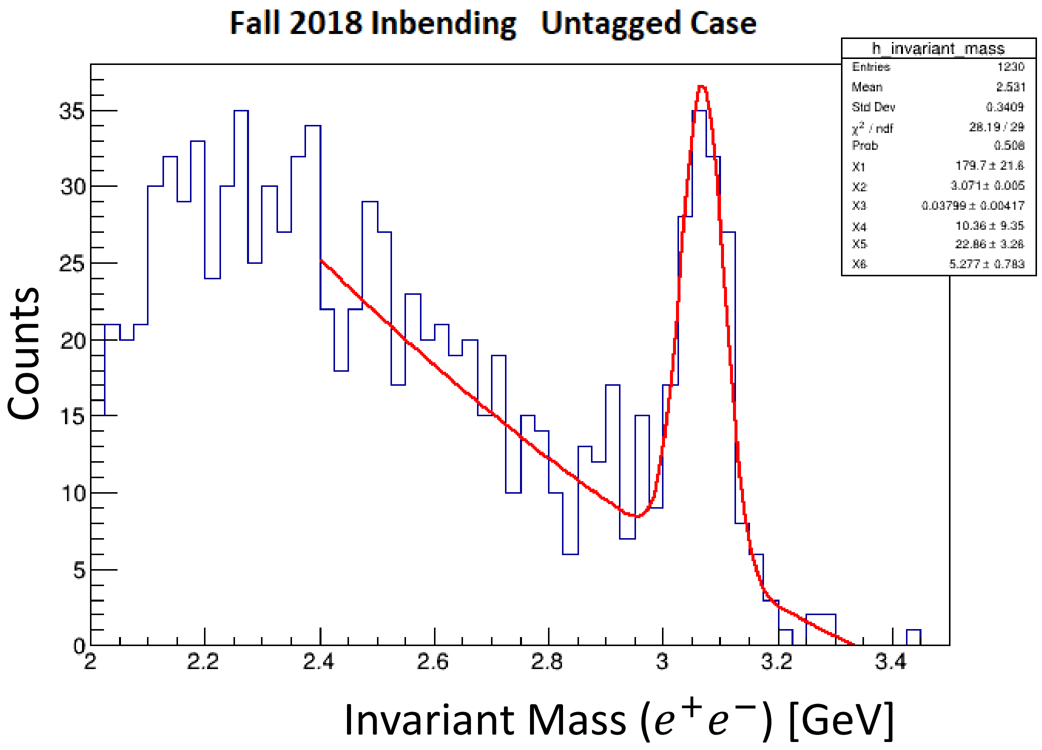
- We obtain the invariant mass of the e^+e^- pair.

$$M^2(e^+e^-) = (\mathrm{k}^+ + \mathrm{k}^-)^2$$

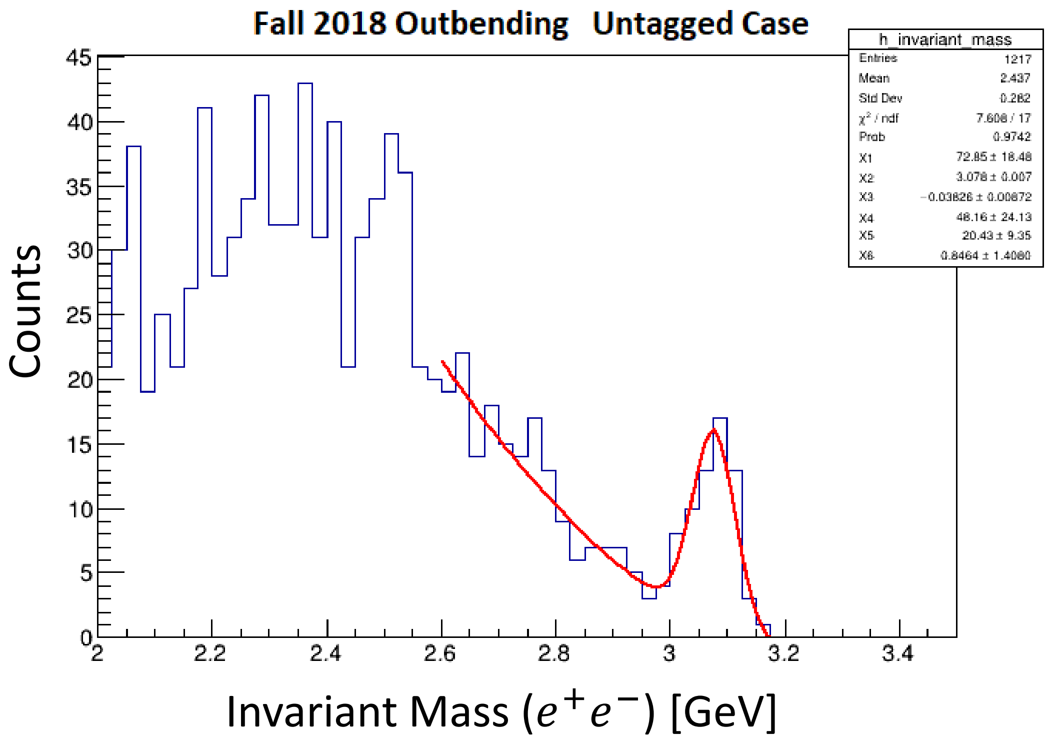
- We apply one more cut in $Q^2 < 0.2\ GeV^2$

Untagged Case $ep \to e^+e^-pX$

$N(J/\psi) = 176 \pm 19$

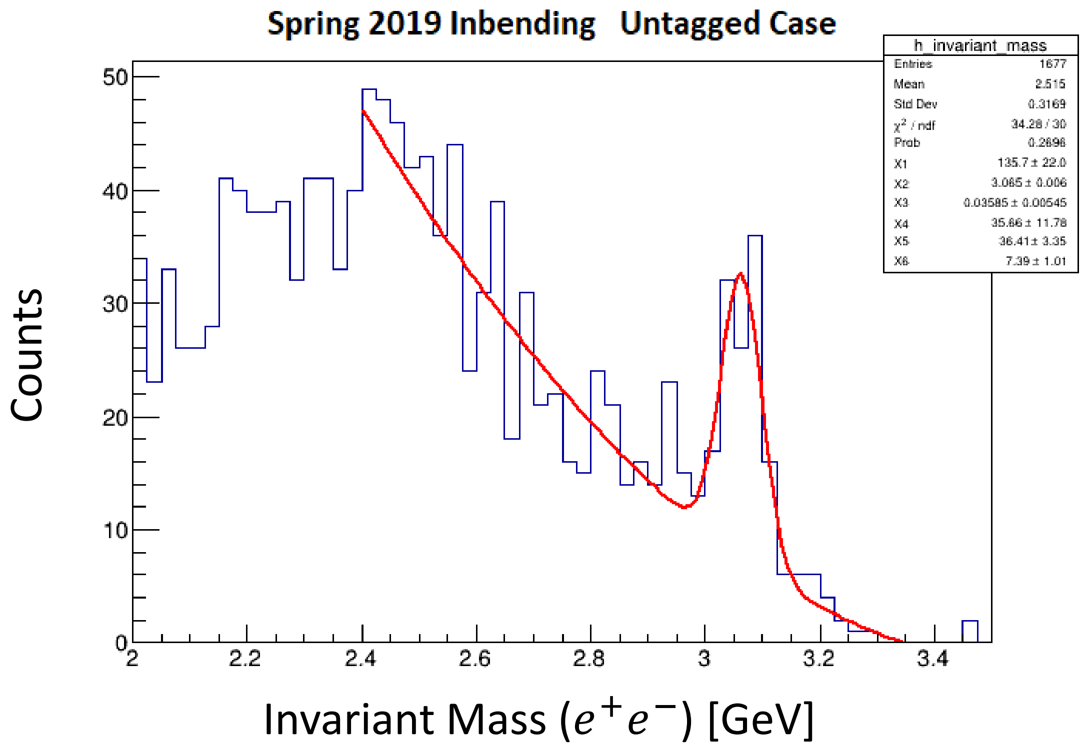


$N(J/\psi) = 72 \pm 18$



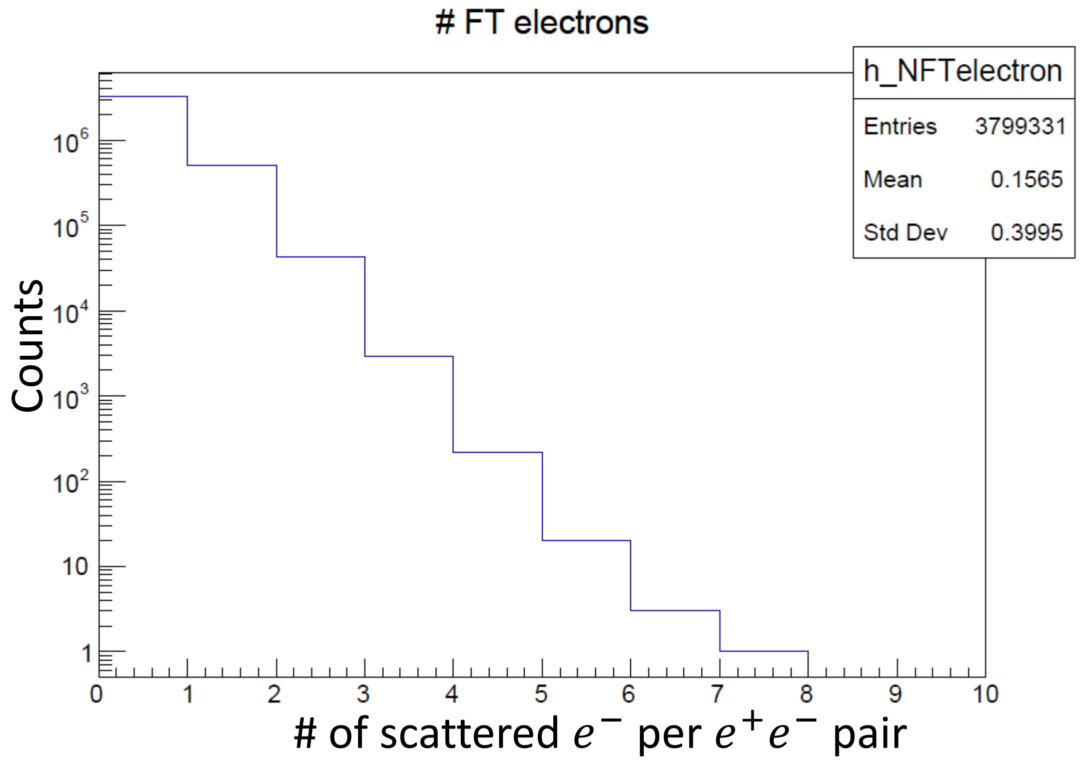
Untagged Case $\boldsymbol{ep \rightarrow e^+e^-pX}$

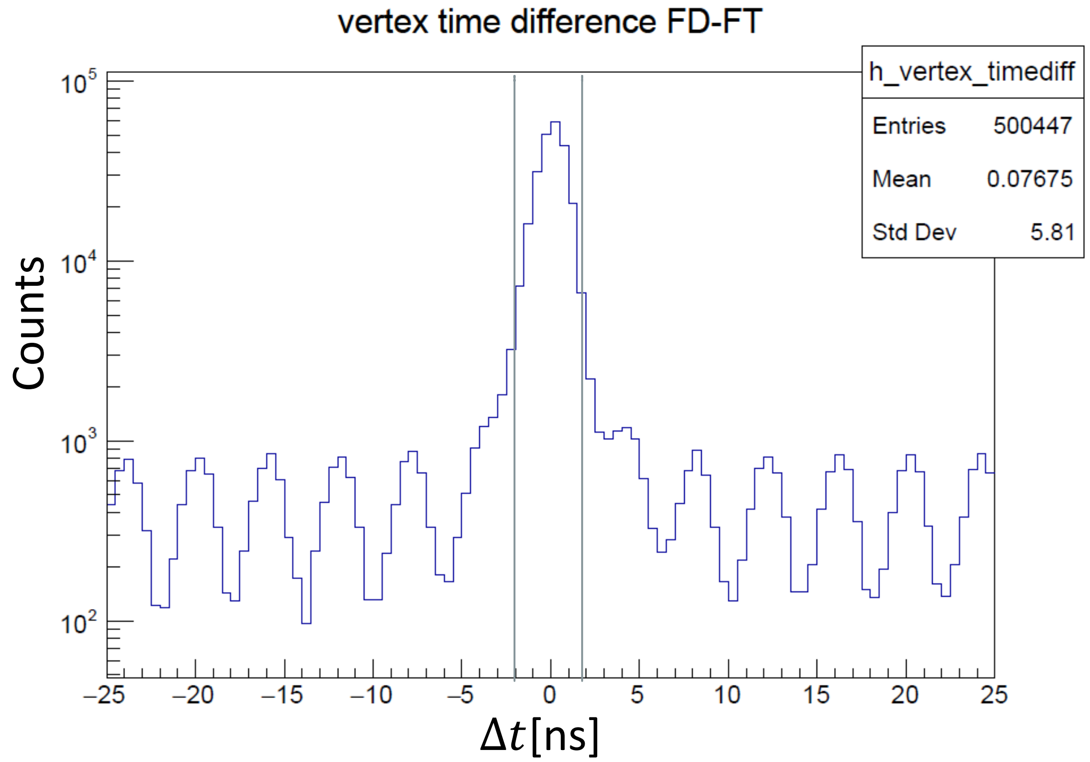
$N(J/\psi) = 135 \pm 22$



Tagged Case $ep \rightarrow e^+e^-e'X$

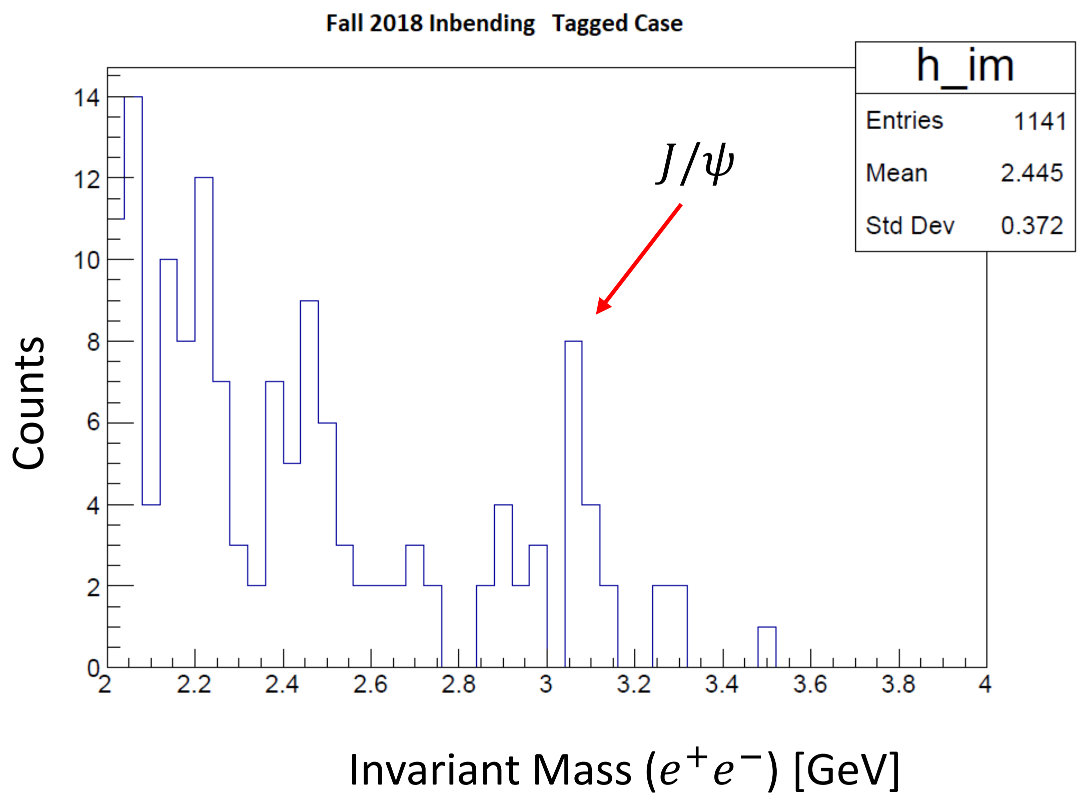
- In addition to the e^+e^- we identify an electron in the Forward Tagger.

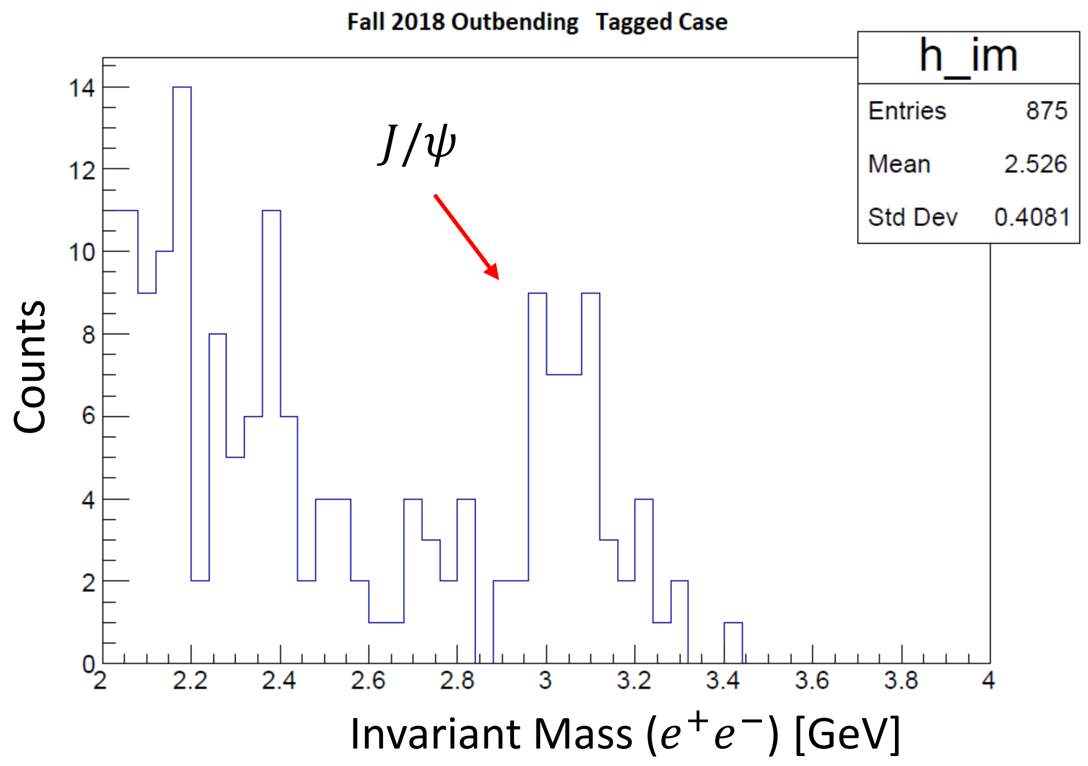




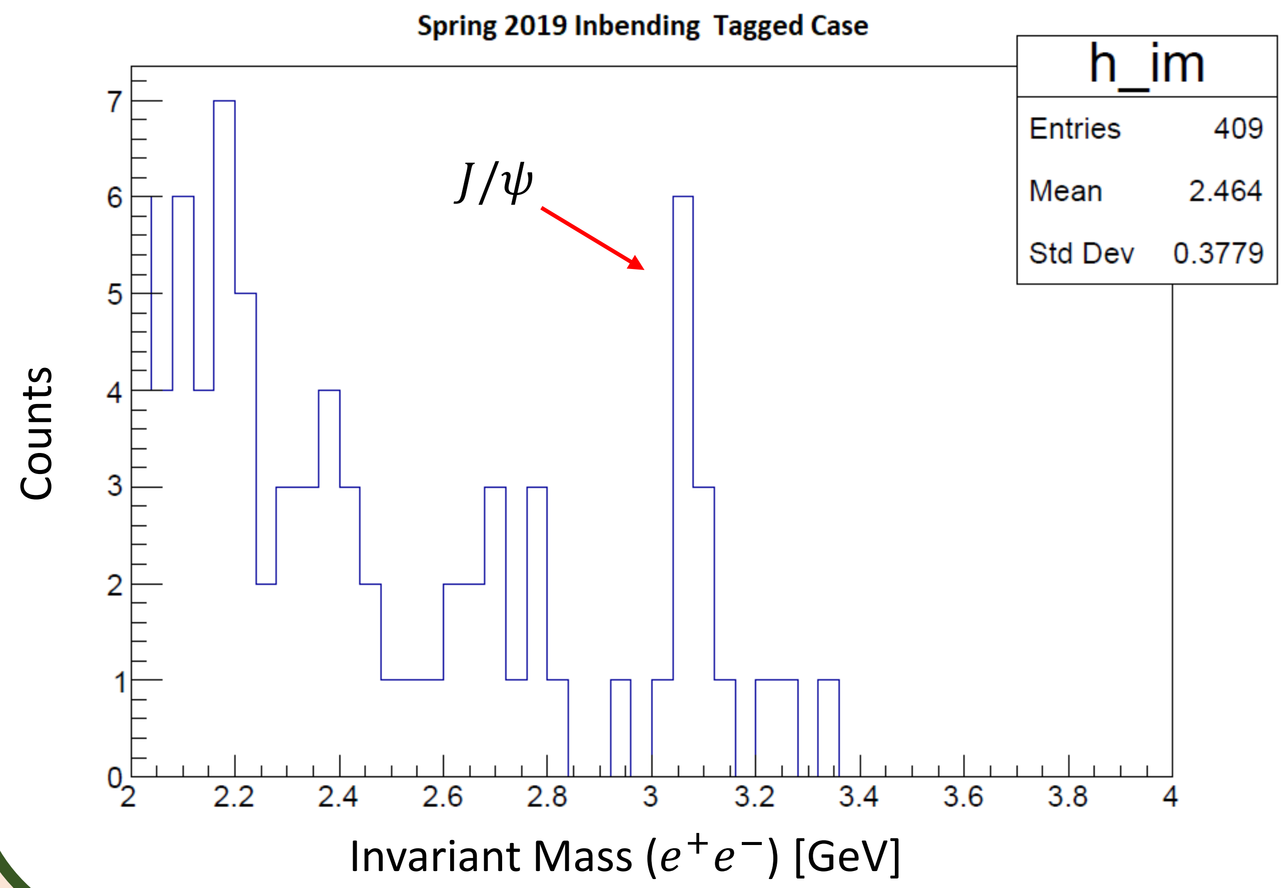
- The momentum of the FT electron was recalculated to account for a bug in the calibration of the pass1 data.

Tagged Case $ep \to e^+e^-e'X$





Tagged Case $ep \rightarrow e^+e^-e'X$

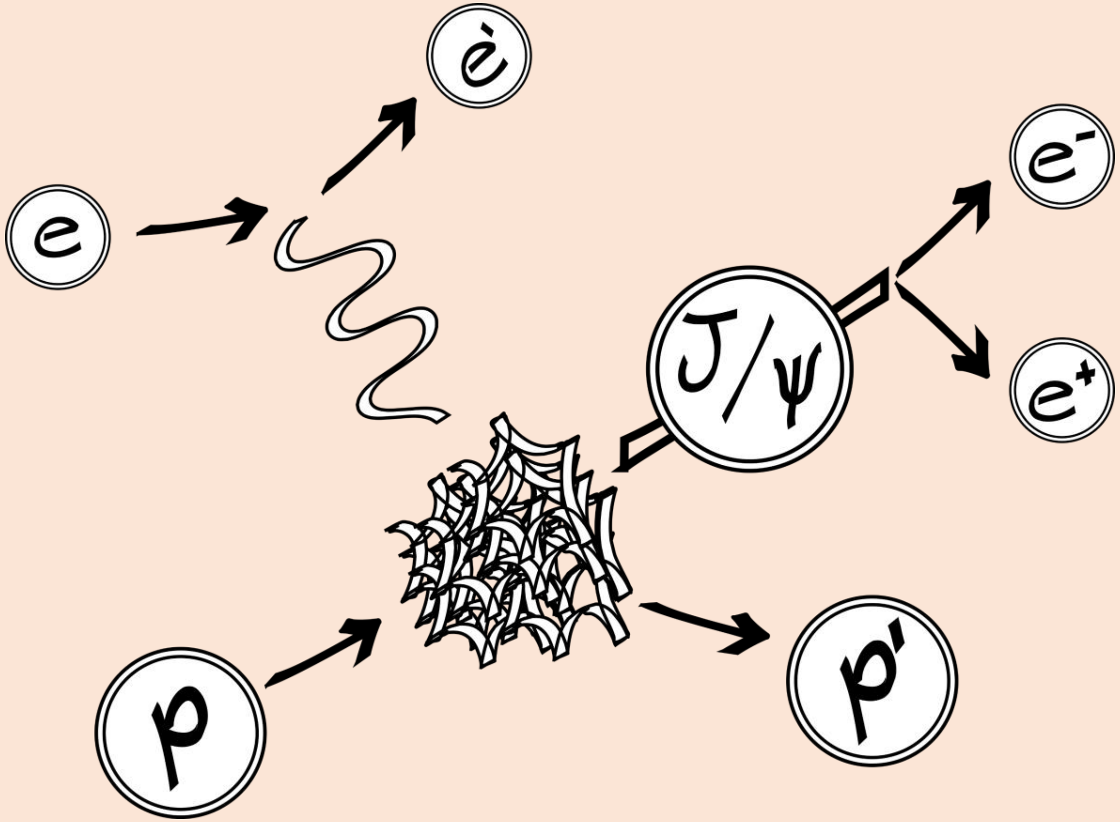


Next Steps

- Obtain the Hadronic mass distribution, W.
- Obtain the total accumulated charge Q_{tot}

$$\mathcal{R}(W) = \frac{N_{J/\psi}(W)}{N_p \cdot Q_{tot}}$$

- Calculate the rate as function of W
- We can repeat this analysis for other tagged reactions such as $ep \rightarrow e^{+}Xe'p$
- **The ultimate goal is to extract the cross sections.**



Thank you!

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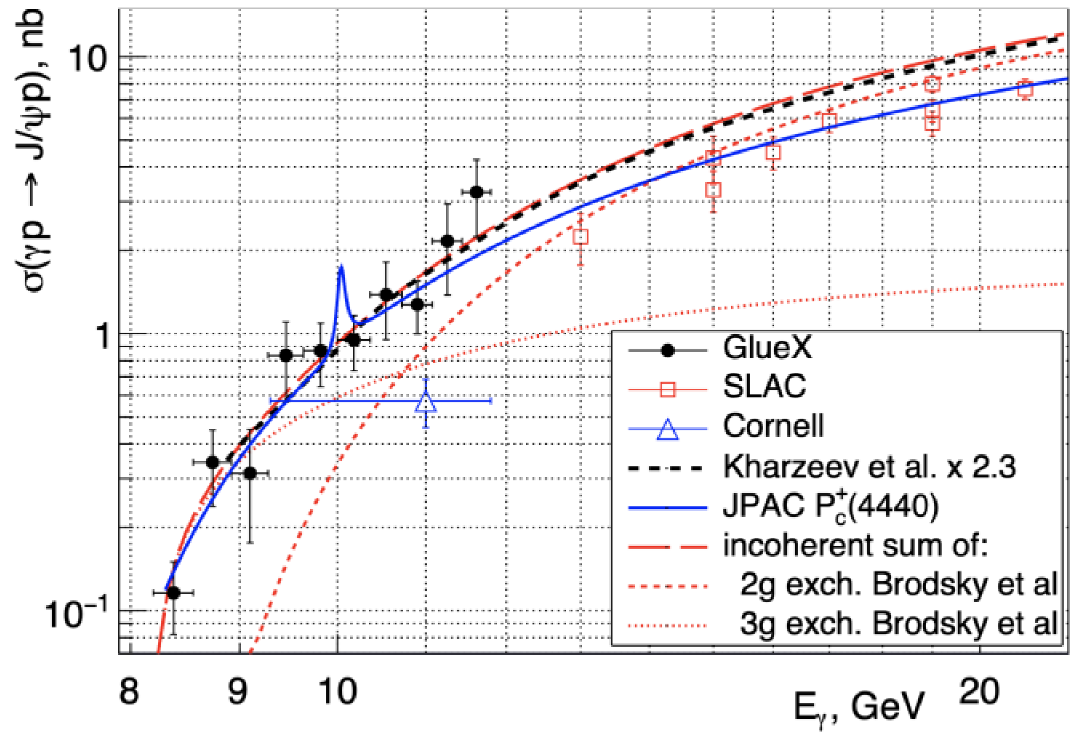
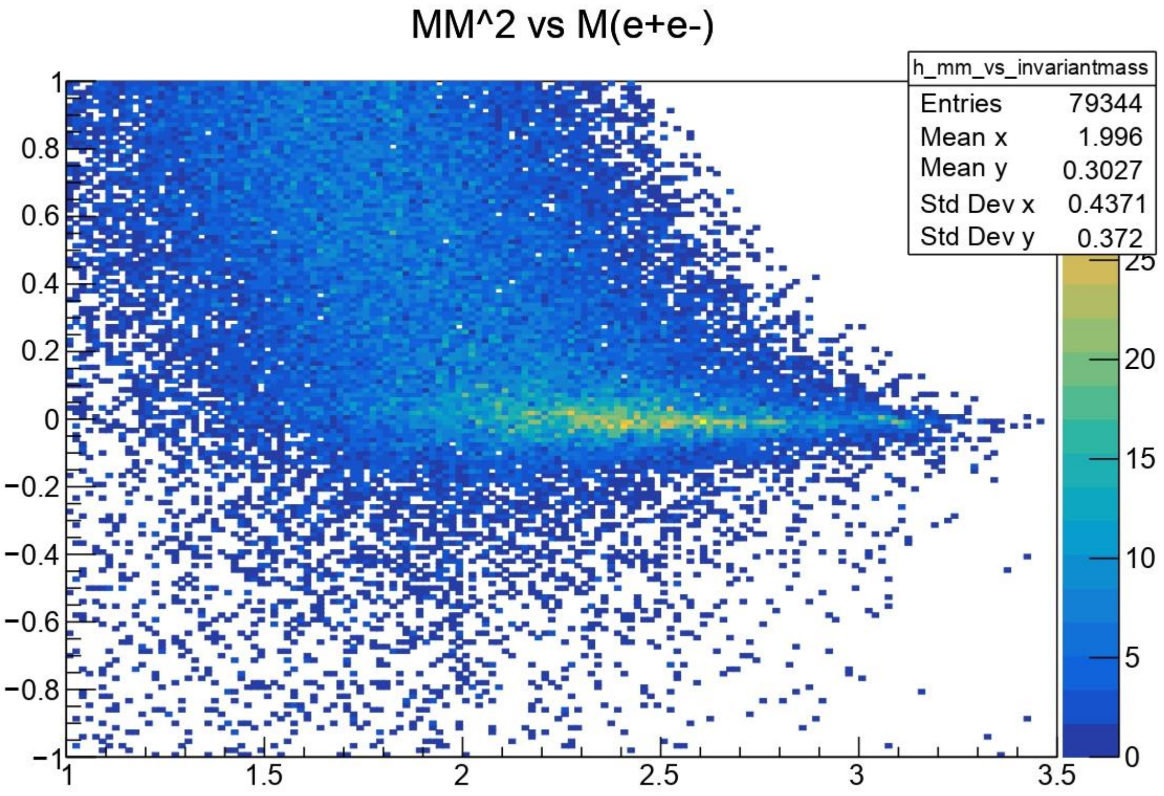
Backup Slides

Near Threshold J/Psi photoproduction



Missing Momentum Analysis



$$|M_X^2| < 0.2 \text{ GeV}^2$$

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

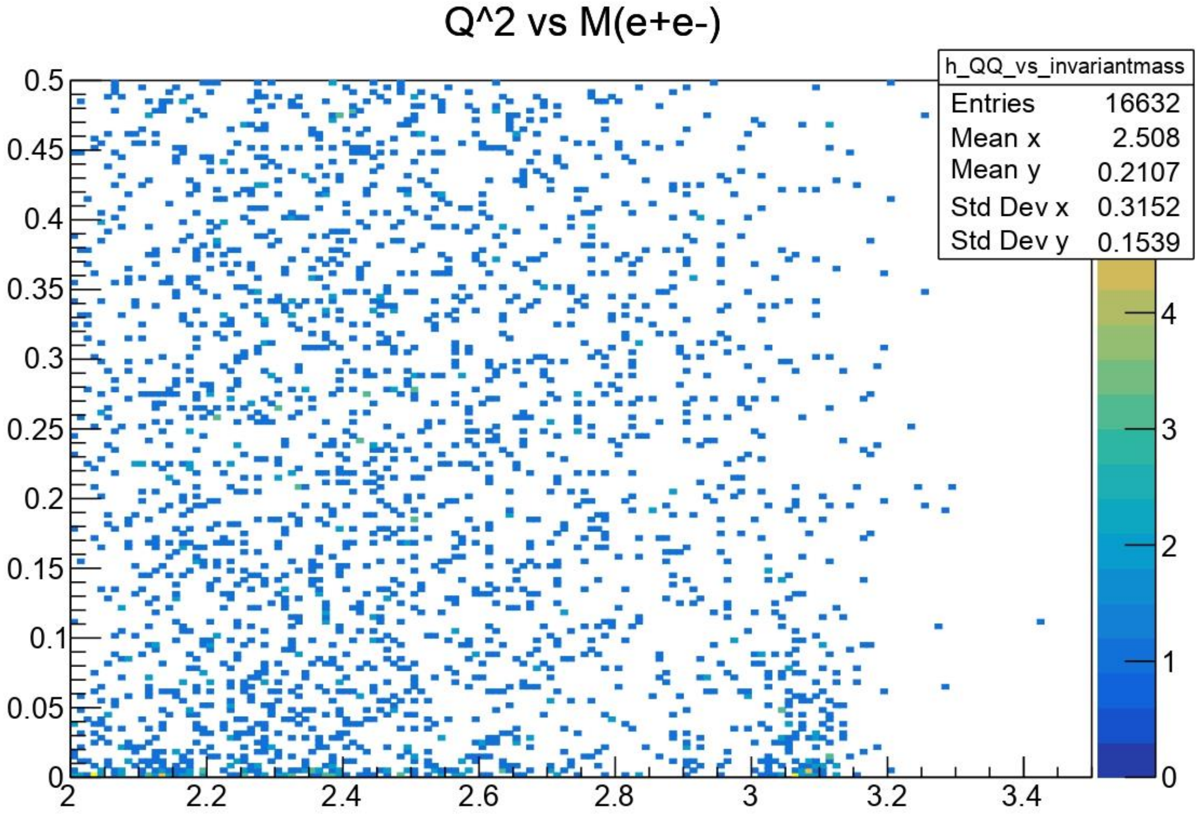
$$\mathrm{p}_X = \mathrm{e} + \mathrm{p} - \mathrm{k}^+ - \mathrm{k}^- - \mathrm{p}'$$

$$M_X^2 = \mathrm{p}_X^2$$

$$M^2(e^+e^-) = (\mathrm{k}^+ + \mathrm{k}^-)^2$$

$$Q^2 = 2 \cdot E_{beam} \cdot (P_X - P_X^z)$$

Q^2 and Invariant mass



$$Q^2 = 2 \cdot E_{beam} \cdot (P_X - P_X^z)$$

$$Q^2 < 0.2$$

$$Q^2 > 0.2$$