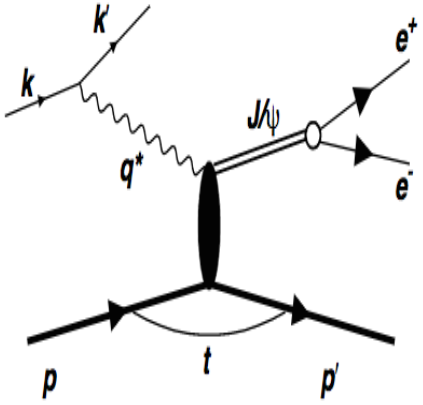
J/ψ Photoproduction Near Threshold With CLAS12

Joseph Newton
April 19, 2020
Old Dominion University

Experiment Overview

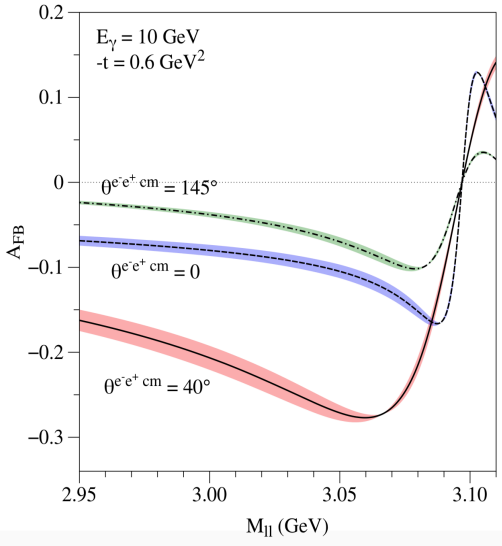
Description

- Electrons accelerated by CEBAF scatter off a liquid Hydrogen target at low scattering angles through the exchange of a quasi-real photon at $Q^2 \sim 0$
- Detect the recoil proton and the e^+e^- from the decay of J/ψ
- Experiment 12-12-001 was approved for 120 days of beamtime on CLAS12 at a luminosity of 10^{35} cm^{-2} s^{-1}



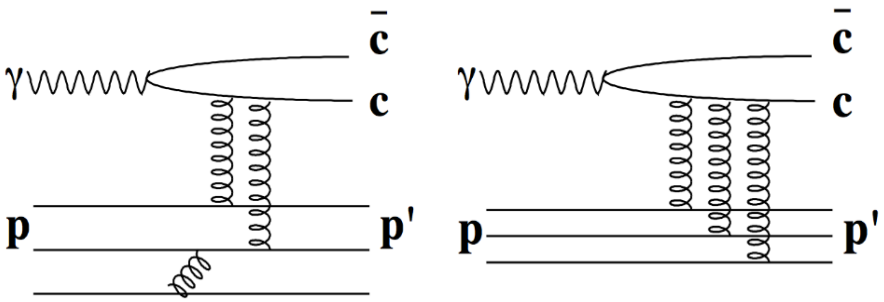
Physics Goals

- Probe the distribution of color charge in the nucleon
  - Measure the t-dependence of the differential cross section of J/ψ photoproduction
- Study the production mechanism of J/ψ near threshold
  - Measure the total cross section as a function of photon energy
- Study the forward-backward asymmetry to access the real part of the Compton scattering amplitude

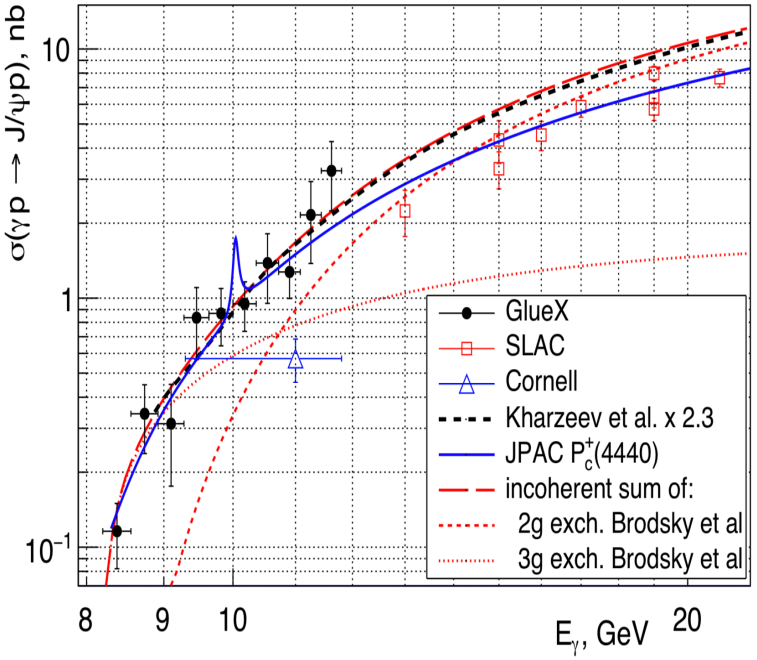


Proposed Models For J/ψ Photoproduction

- The incoming photon couples to the gluon field through an intermediate virtual charm-anti-charm pair
- Near threshold, momentum transfer becomes large and all three valence quarks must exchange energy in the form of gluons for the elastic production of J/ψ. This will allow the study of gluonic form factors of the proton



Available Experimental Results



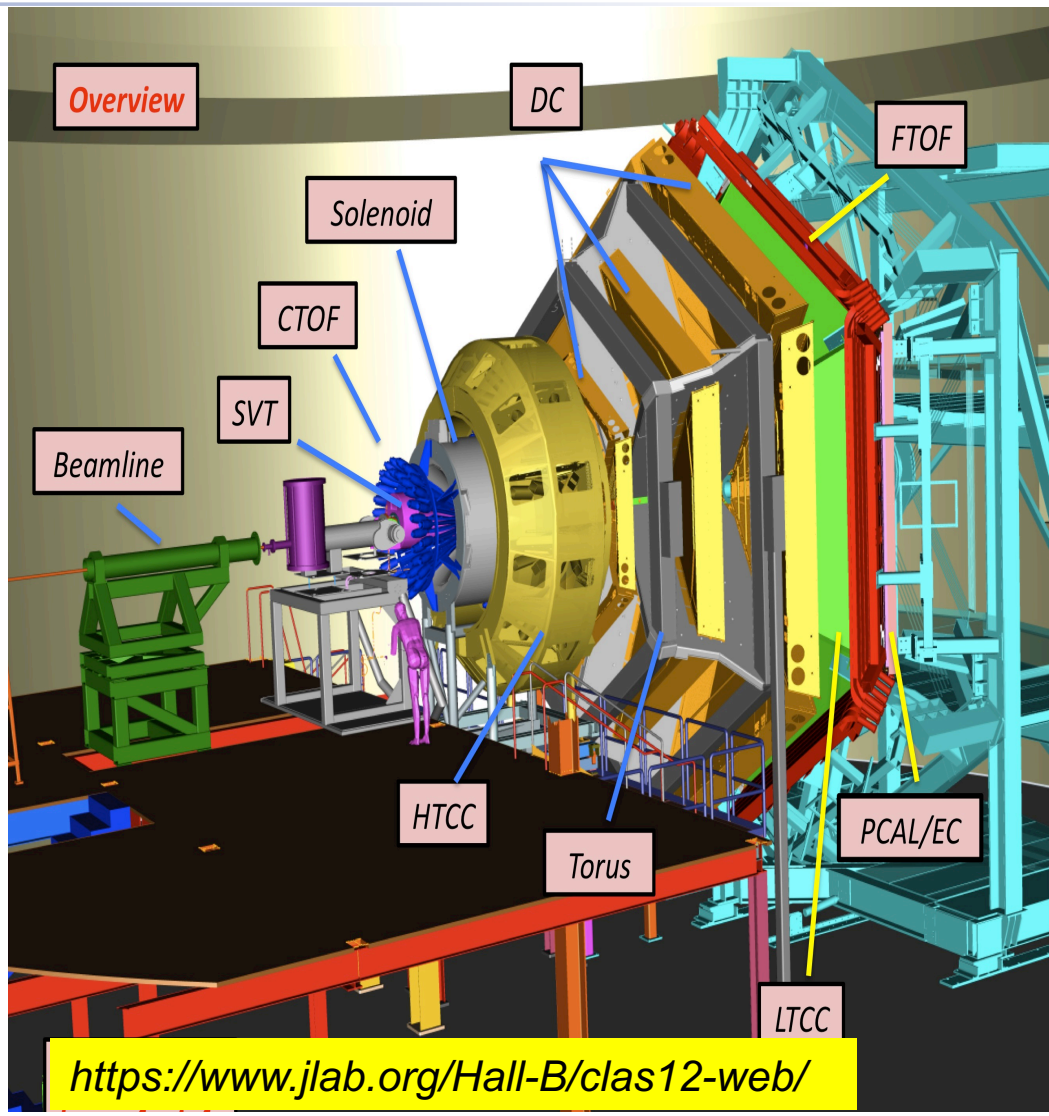
$$\frac{d\sigma}{dt} = N_{2g}\frac{(1-x)^2}{R^2M^2}F_{2g}^2(t)(s-m_p^2)^2$$

$$\frac{d\sigma}{dt} = N_{3g}\frac{(1-x)^0}{R^4M^4}F_{3g}^2(t)(s-m_p^2)^2$$

*S.J. Brodsky, E. Chudakov, P. Hoyer, and J.M. Laget. Phys. Rev. Lett. (2008)
*CLAS12 Collaboration, "Timelike Compton Scattering and J/ψ Photoproduction on the Proton in e+e- Pair Production with CLAS12 at 11 GeV", Thomas Jefferson National Accelerator Facility PAC 39 Proposal, (May 2012).

CLAS12 Overview & Conditions of the Hall-B RG-A

Fall 2018 Run Conditions	
Magnetic Fields	Maximum current settings of the Torus and Solenoid magnets
Beam Energy	10.6 GeV
Target	Liquid Hydrogen
Beam Current	50 nA
Time Period	September 2018 to November 2018



J/ψ Detection With CLAS12

- In near threshold J/ψ production, all three final state particles are going forward and will be detected in the CLAS12 forward detector

$$ep \rightarrow \mathrm{J}/\psi\, p\,(e') \rightarrow e^+e^-p(e')$$

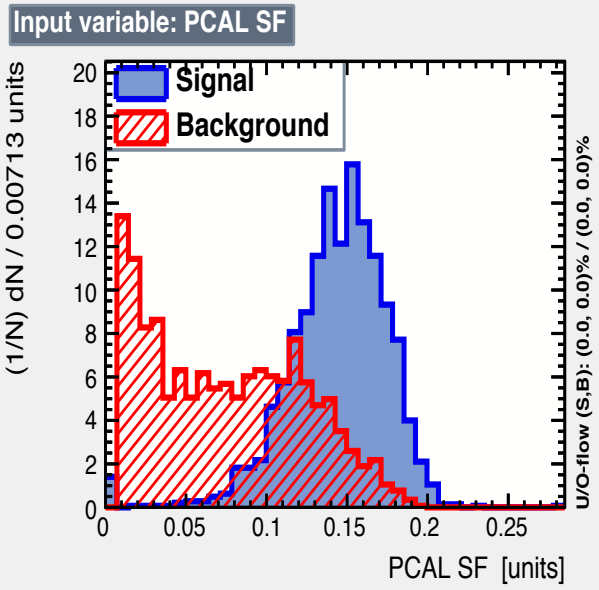
- Performance of the CLAS12 forward detector allows the identification of an e+, e- and a proton up to p ~ 5 GeV/c.

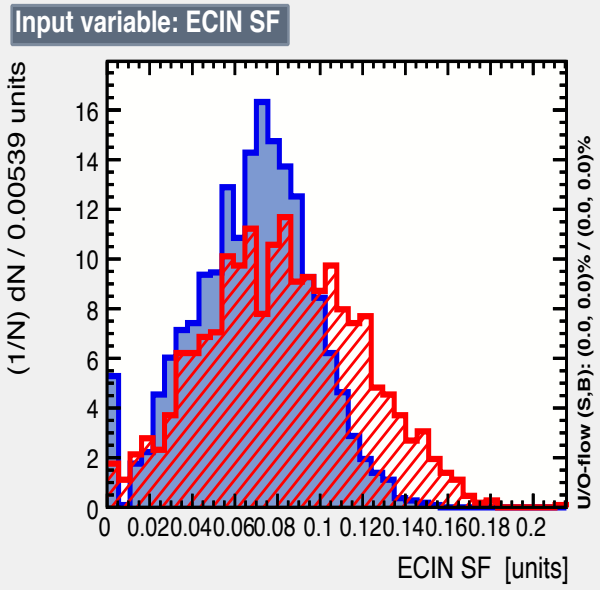
- Above 5 GeV/c, additional PID selection mechanisms were developed to identify electrons and reject pions. Multi-variate analysis was used for this purpose.

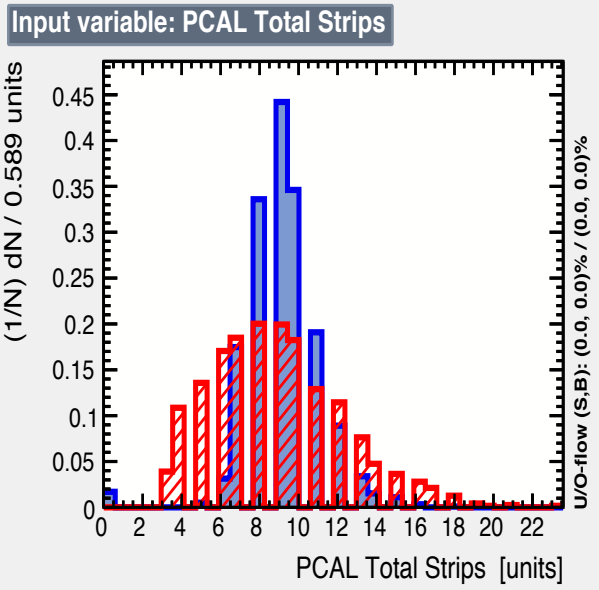
- From the decay of J/ψ, an e^+e^- pair gets detected from a combination of information Drift Chambers (DC) for tracking, an Electromagnetic Calorimeter (ECAL), and the High-Threshold Cherenkov Counter.

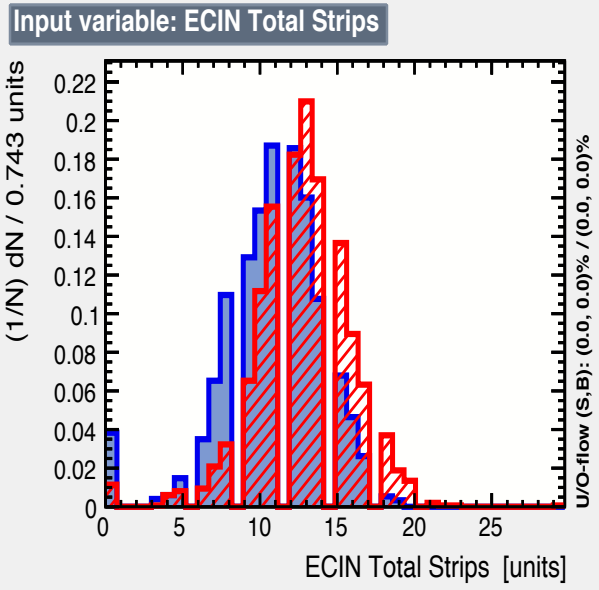
- The scattered proton's β is measured with the Forward Time-of-Flight (FTOF).

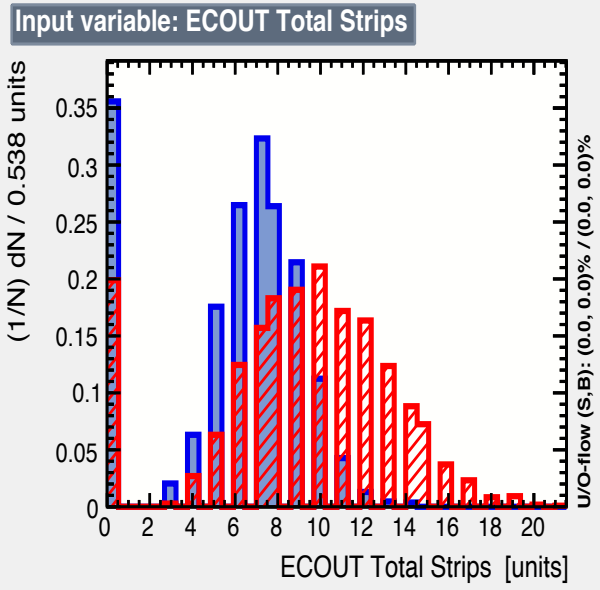
Distinguishing Signal vs. Background For Particle ID At High Momenta With A.I.

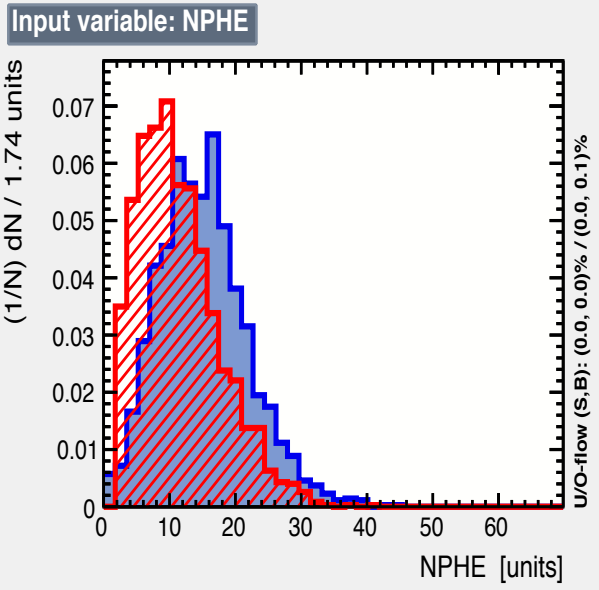






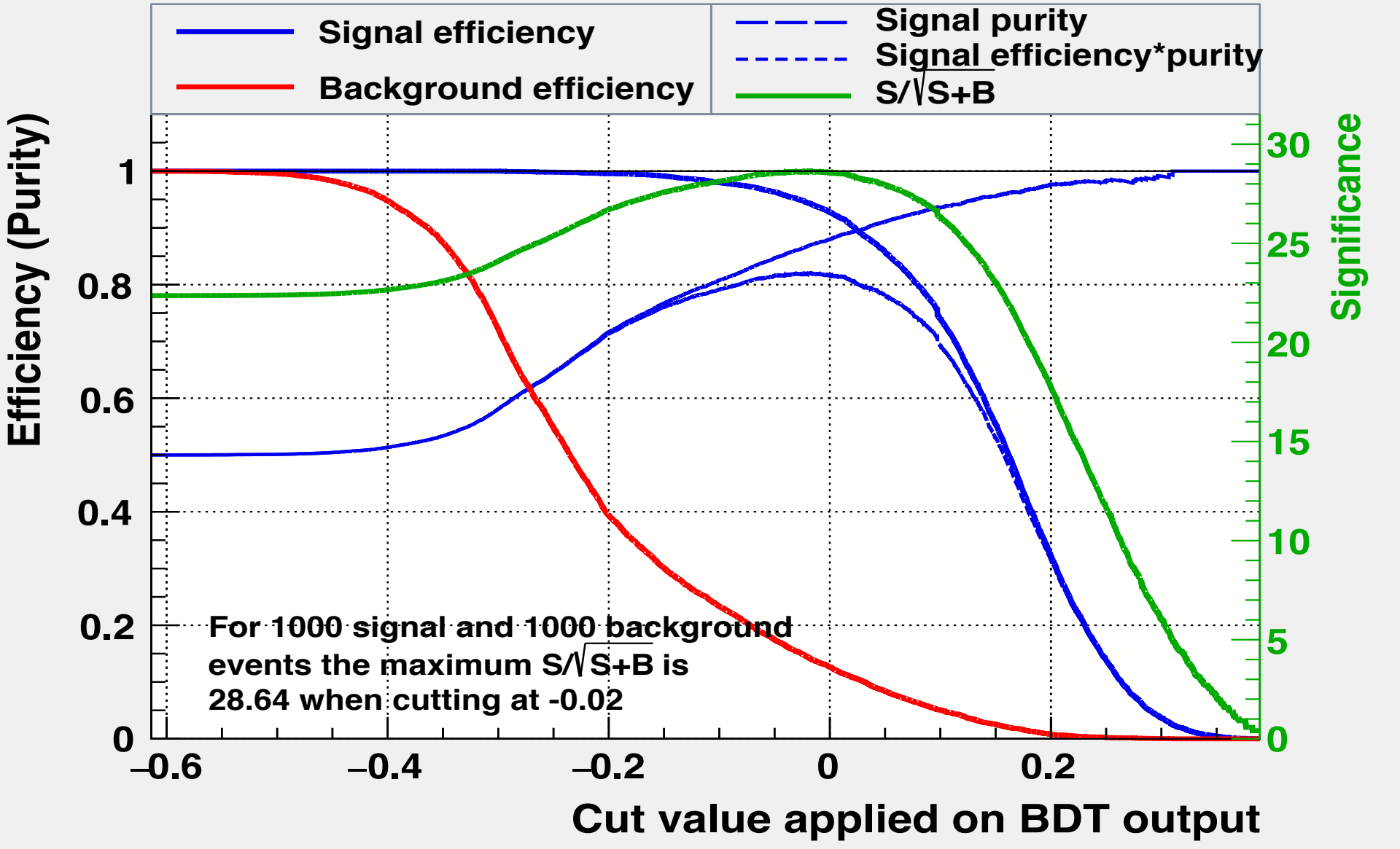






Optimal Cut Value Using The Boosted Decision Tree Machine Learning Method

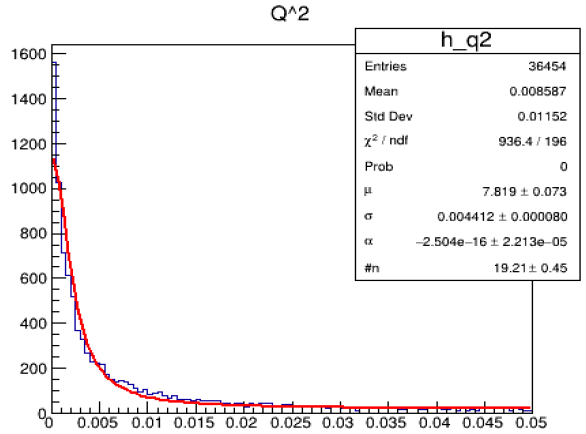
Cut efficiencies and optimal cut value

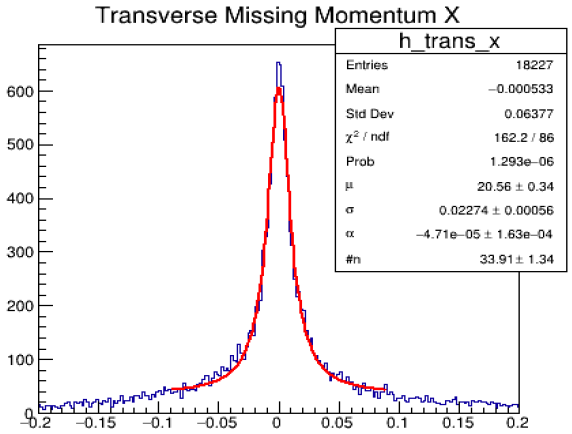


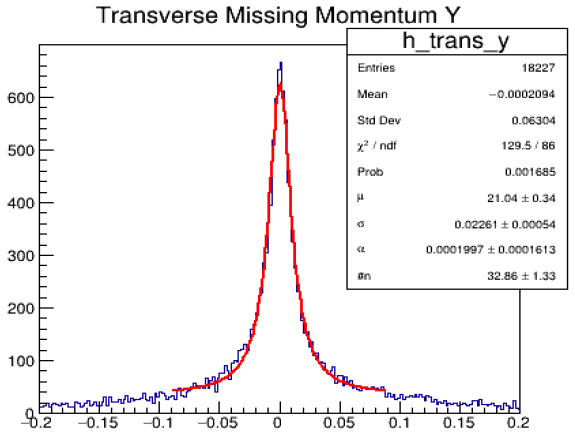
Development Of Event Selection Criteria Using Simulations

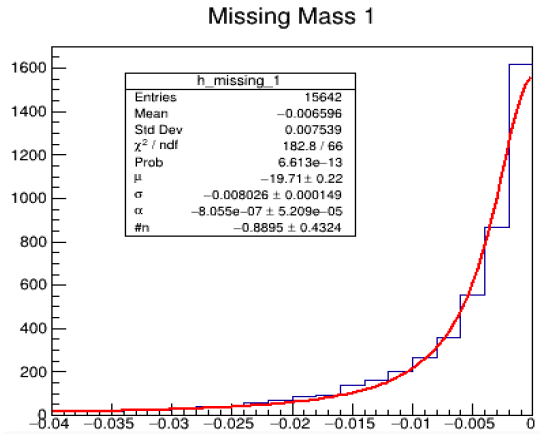
Establishing criteria for event selection is done to understand the measurement of the un-detected forward scattered ($\theta \sim 0$) electron after the exchange of a quasi-real photon. The transverse missing momentum, Q^2, and missing mass were analyzed to develop selection cuts

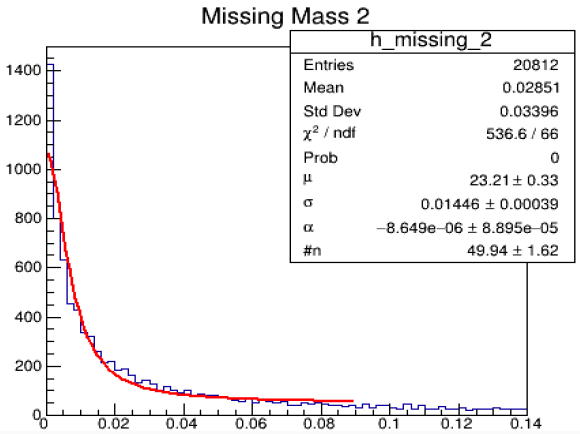
$$ep \rightarrow e^+e^-p'(\boldsymbol{e'})$$











Q^2 J/Psi MC Resolution $\left(\boldsymbol{\sigma = 0.0044\ \frac{GeV^2}{c^2}}\right)$.

$\frac{P_x}{p}$ J/Psi MC Resolution $(\boldsymbol{\sigma = 0.02274})$

$\frac{P_y}{p}$ J/Psi MC Resolution $(\boldsymbol{\sigma = 0.02261})$

$M_{e-}{}^2$ J/Psi MC Resolution $(\boldsymbol{\sigma = 0.008026})$

$M_{e+}{}^2$ J/Psi MC Resolution $(\boldsymbol{\sigma = 0.01446})$

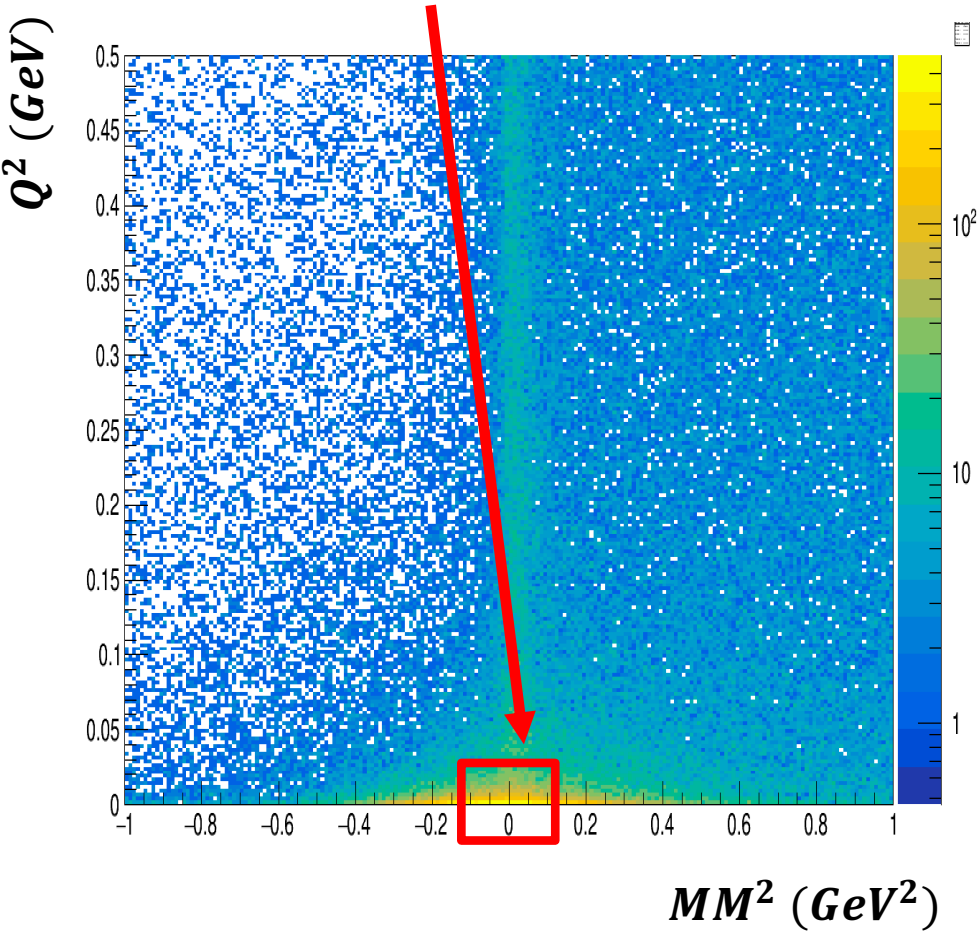
Event Selection For Quasi-Real Photoproduction From Fall 2018 Data

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

Q^2 and Missing Mass Criteria…..

$Q^2 < 0.03$

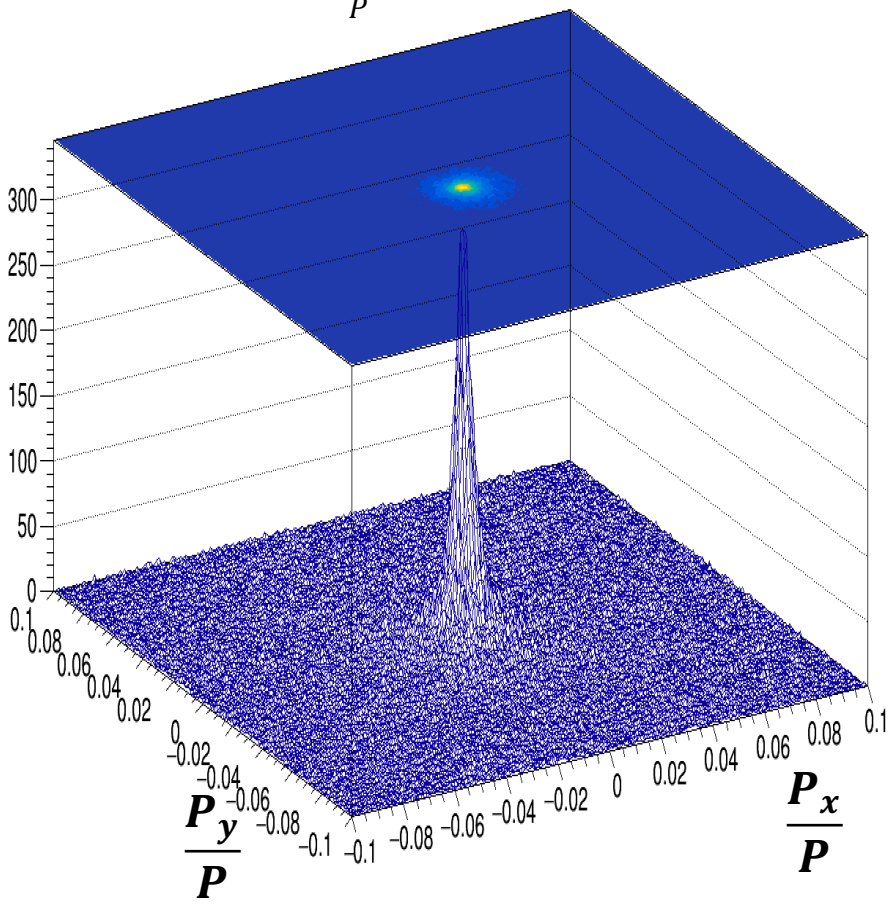
$-0.06 < MM^2 < 0.1$



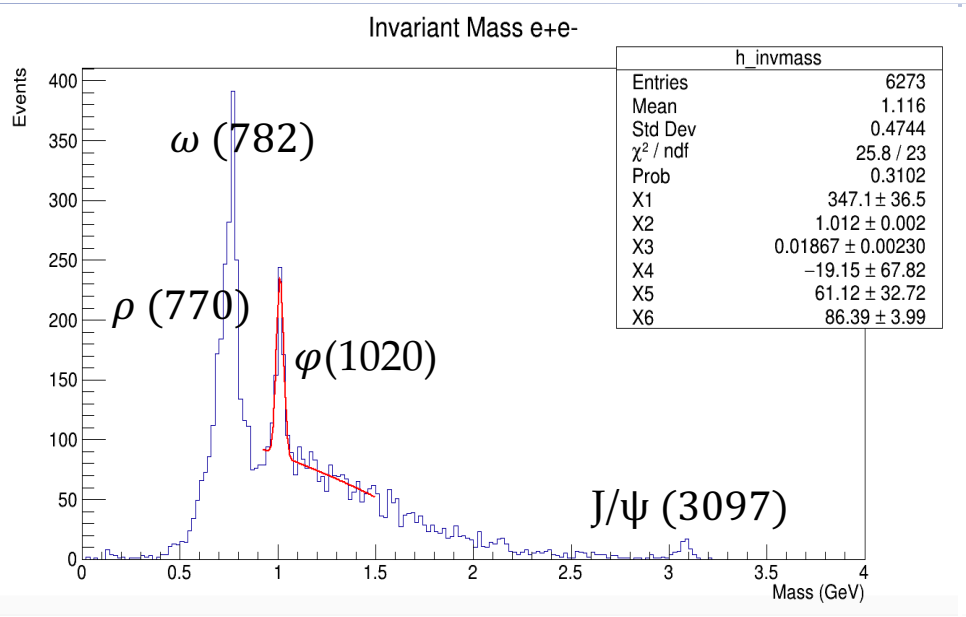
Transverse Missing Momentum Criteria…..

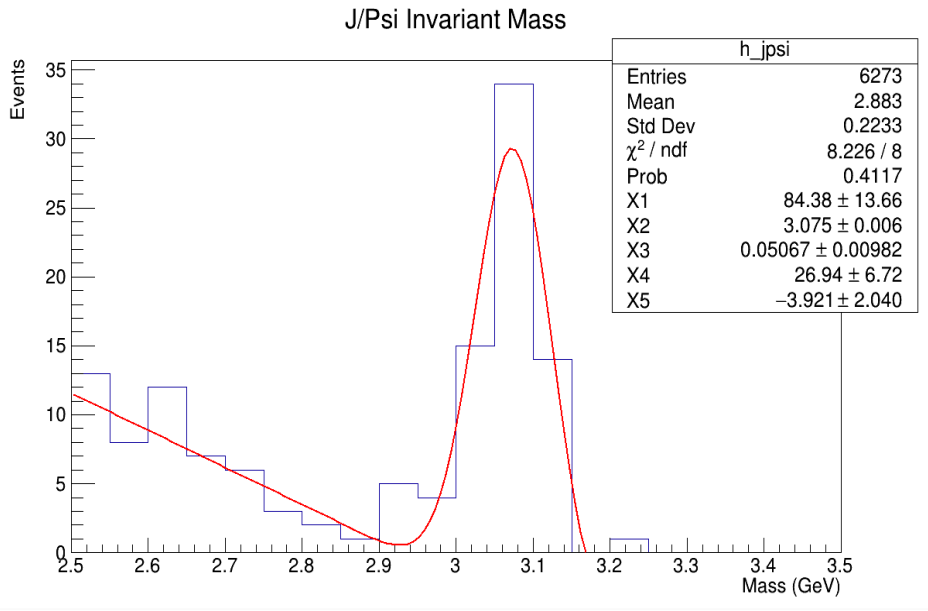
$-0.16 < \frac{P_x}{P} < 0.16$

$-0.16 < \frac{P_y}{P} < 0.16$

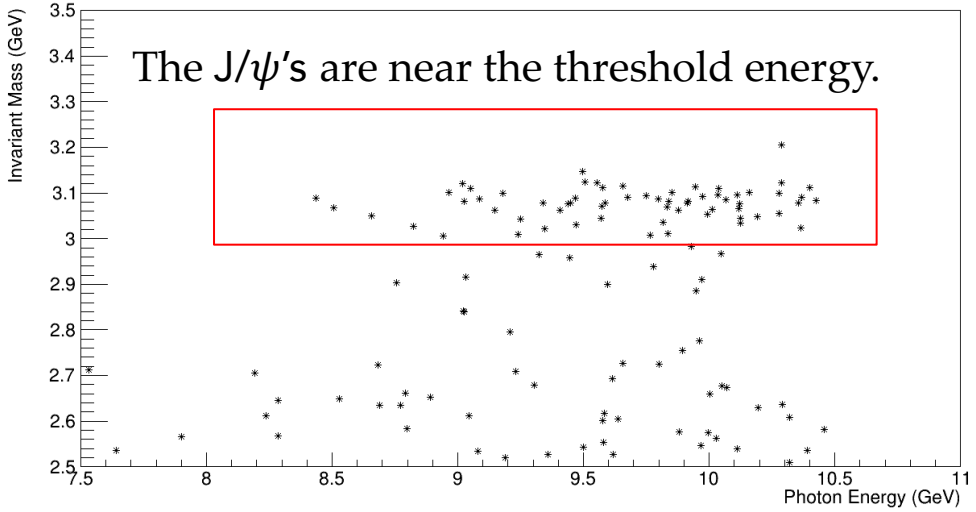


Invariant Mass From Fall 2018 Data





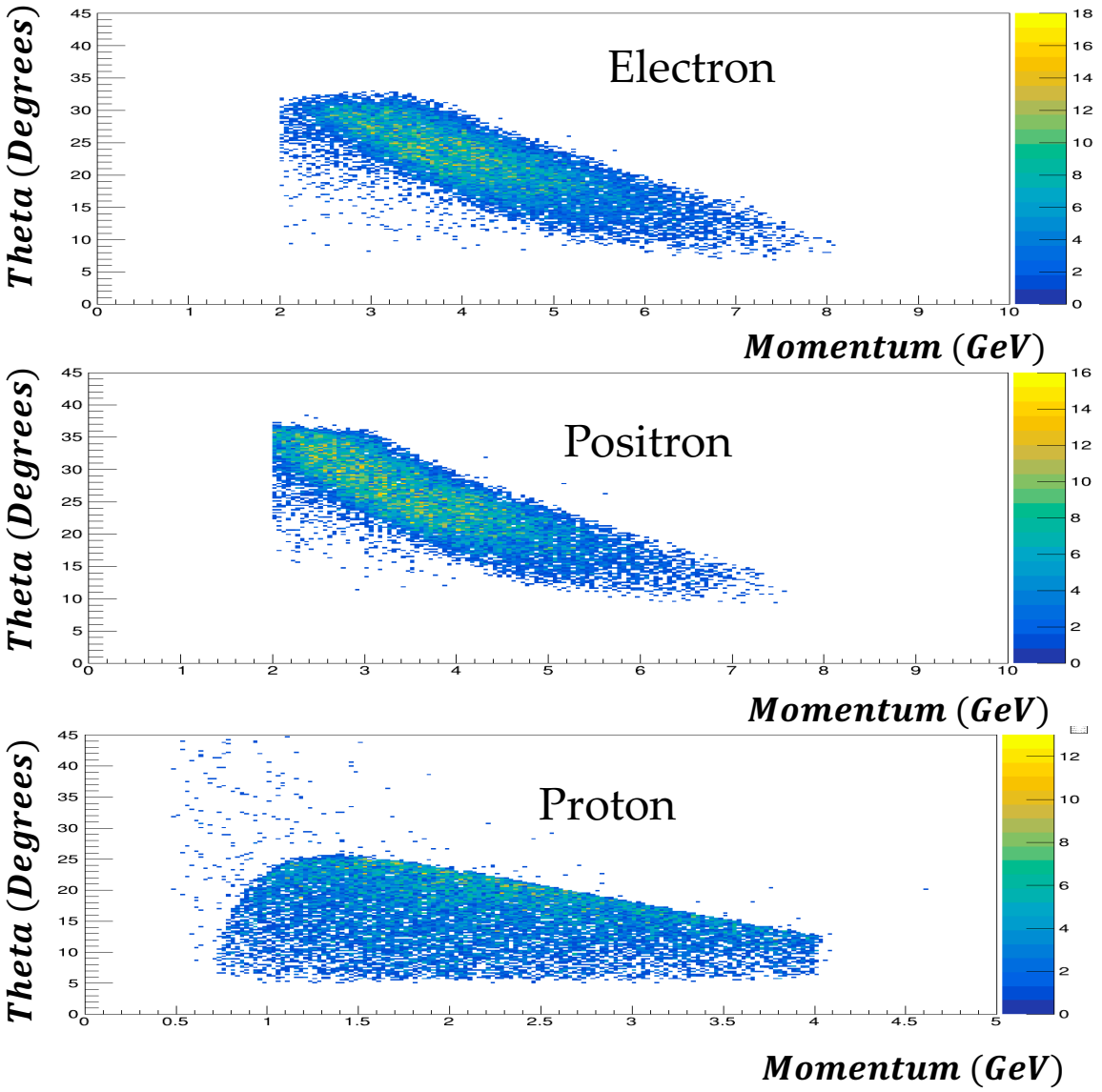
- Using the exclusivity cuts, the invariant mass of the e+e- pair was calculated to show the reconstruction of vector mesons
- With this limited Fall 2018 dataset, approximately 84 J/ψ's were extrapolated from the fit



Next Steps

- Analysis framework with particle identification and event selection nearly complete
- Pass1 data processing of Fall 2018 is halfway complete
- Pass1 data processing for Spring 2018 & Spring 2019 will commence later this year
- Acceptances and normalization using Bethe-Heitler MC simulations will be completed with latest software releases
- Kinematic fitting & momentum corrections to be developed for this reaction.

Back-Up Slides

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

- Event Generator: Two-Gluon Exchange Cross Section For J/ψ Photoproduction
- CLAS12 Simulation Software: GEANT4 Monte Carlo (GEMC)
- CLAS12 Reconstruction Software: COATJAVA
- Kinematics of the three final-state particles were studied in the Forward Detector (FD)