J/ψ Photoproduction Near Threshold With CLAS12

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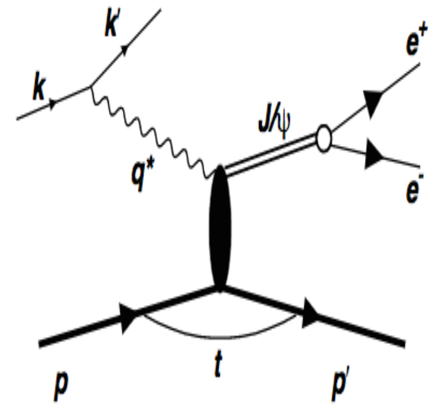
Outline

- Experiment Overview
- Particle Identification
- Energy Corrections For Radiative Photons
- Event Selection Studies
- Fiducial Volume Analysis
- Effect of Background Merging On MC Data
- Invariant Mass For Available Fall 2018 Dataset
- Next Steps

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 $Q^2 \sim 0$



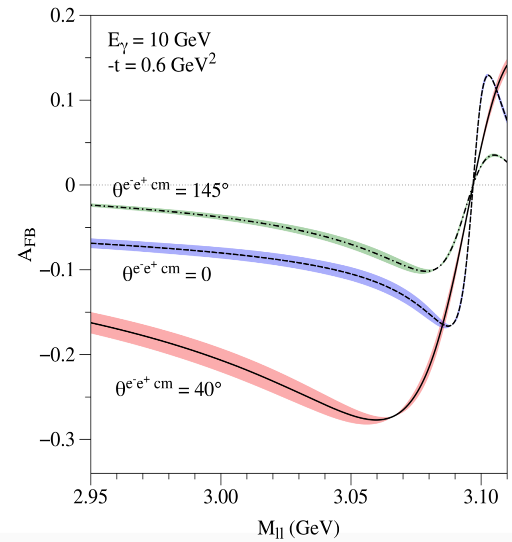
- Detect the recoil proton and the e^+e^- from the decay of J/ψ

- 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

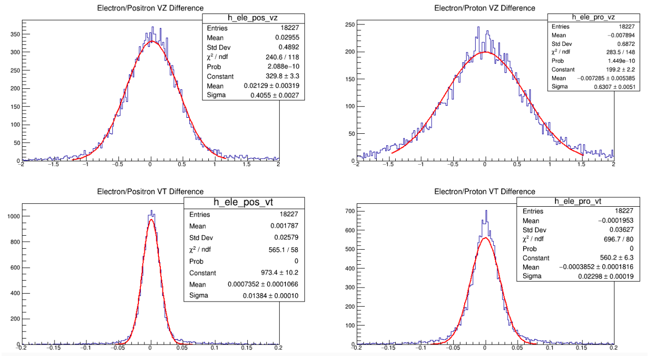


- Study the forward-backward asymmetry to access the real part of the Compton scattering amplitude

*O. Gryniuk, and M. Vanderhaeghen. Phys. Rev. Lett. (2016)

J/Psi Photoproduction Particle ID Strategy

- For e^+e^- detection with $p < 5$ GeV….
  - Use REC::Particle.chi2pid to constrain sampling fraction's deviation to expected mean value
  - Keep the same HTCC photoelectrons (**2**) cut & PCAL minimum energy cut (**60 MeV**) from the CLAS12 event builder
- For proton detection…
  - Restrict to forward detector for J/ψ
  - Use REC::Particle.chi2pid to constrain the proton's deviation from the expected vertex time for a given FTOF timing resolution
- For e^+e^- detection with $p > 5$ GeV…
  - For positrons, utilize the Boosted Decision Tree output value cut (**-0.02**) from ROOT's multi-variate analysis package. The following variables are used: PCAL E/p, ECIN E/p, PCAL # of Strips, ECIN # of Strips, ECOUT # of Strips, Number of HTCC Photoelectrons from missing neutron events
  - For electrons, utilize a cut-based approach…
    - ECIN SF vs. PCAL SF diagonal cut, PCAL Strips < (**16**), ECIN Strips < (**20**), ECOUT Strips < (**13**), PCAL M2U/DU < (**44**), ECIN M2UVW/DUVW < (**165**), ECOUT M2UVW/DUVW < (**130**), NPHE >= (**3**)
- For e^+e^-p vertex constraints (Work in Progress)…
  - Electron-Positron VZ MC Resolution ($\boldsymbol{\sigma = 0.41\ cm}$)
  - Electron-Proton VZ MC Resolution ($\boldsymbol{\sigma = 0.63\ cm}$)
  - Electron-Positron VT MC Resolution ($\boldsymbol{\sigma = 0.0138\ ns}$)
  - Electron-Proton VT MC Resolution ($\boldsymbol{\sigma = 0.0227\ ns}$)

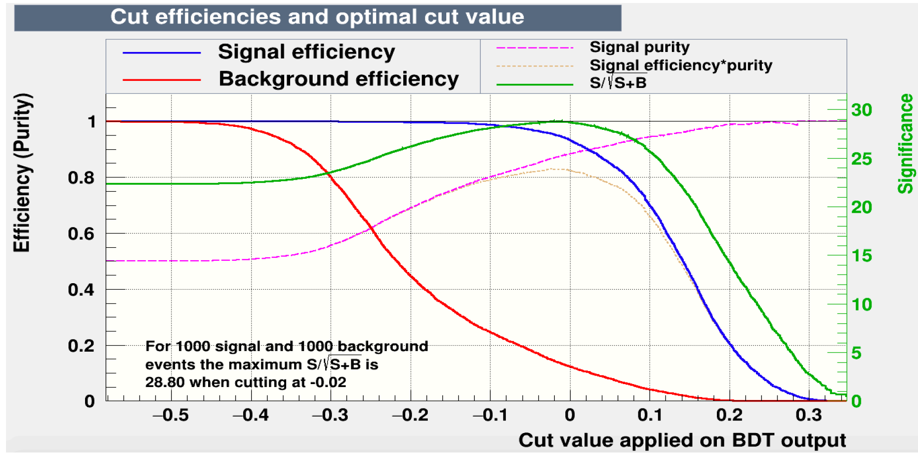


Distinguishing Signal vs. Background For e+e- Particle ID At (p > 5 GeV) With A.I.

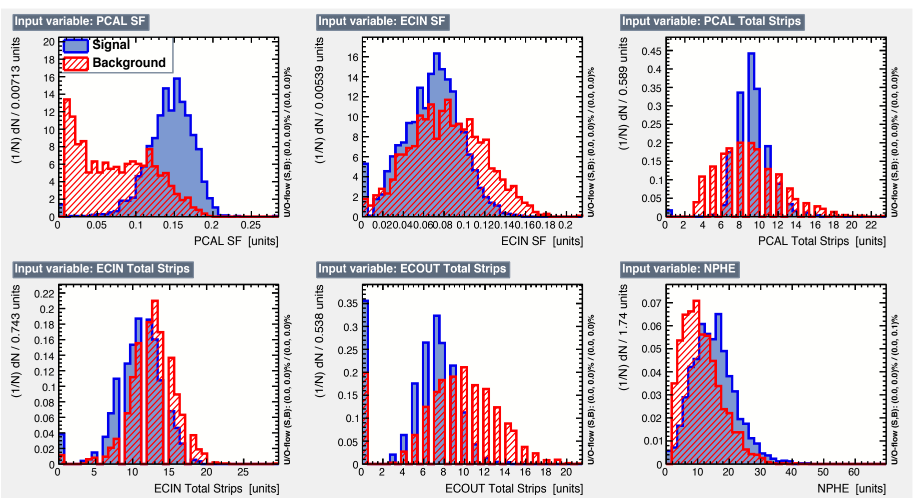
*For positrons with p > 5 GeV, ROOT TMVA (multi-variate analysis) can be implemented to distinguish pions and positrons.

*Development of training samples with background and signal variables can feed into a Boosted Decision Tree (BDT) to train the AI.

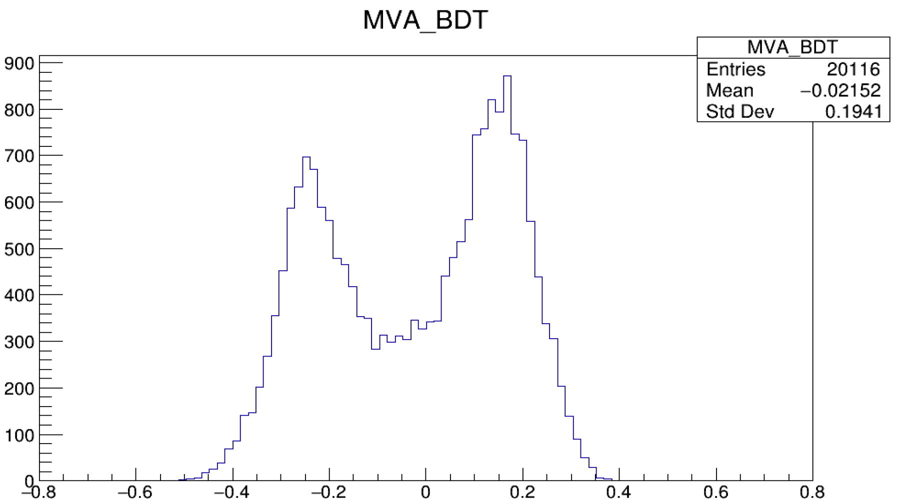
*The BDT algorithm can be included in analysis code to make selection cuts on an event-by-event basis



Efficiency vs. cut plot to determine optimal BDT value for classifying signal or background.



Background and signal input parameters.



BDT output values for data sample with background (pions) and signal events (positrons) with 10000 each

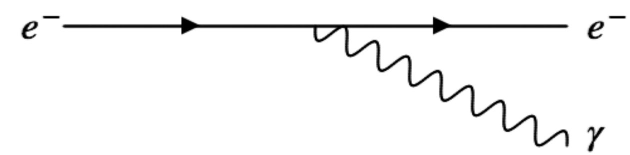
Effects of Radiative Photons On J/Psi Reconstruction

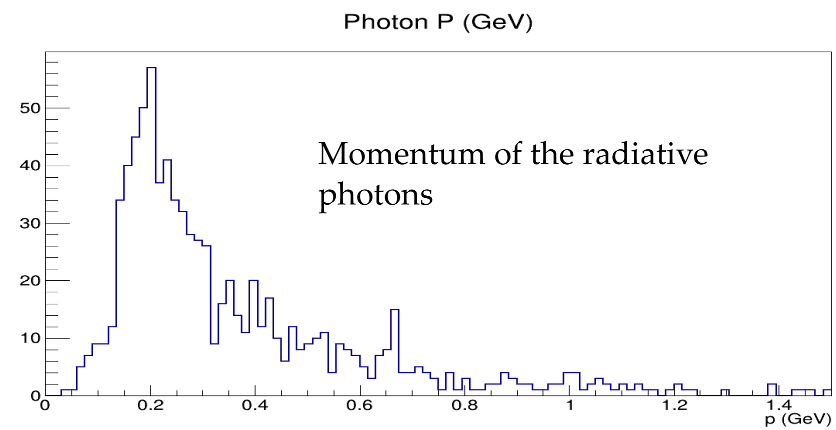
*Electrons and positrons from the decay of J/Psi lose energy, which can result in radiative photons depositing energy into ECAL.

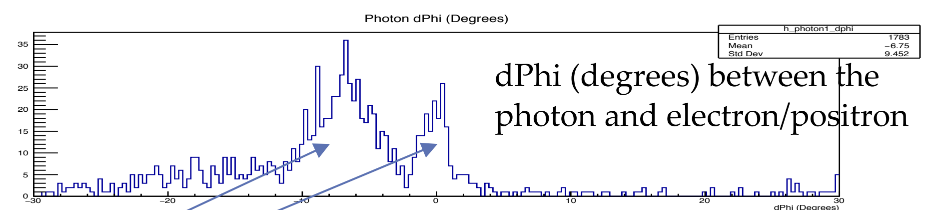
*Photons are selected by comparing the theta and phi angle of the photon to that of the electron or positron.

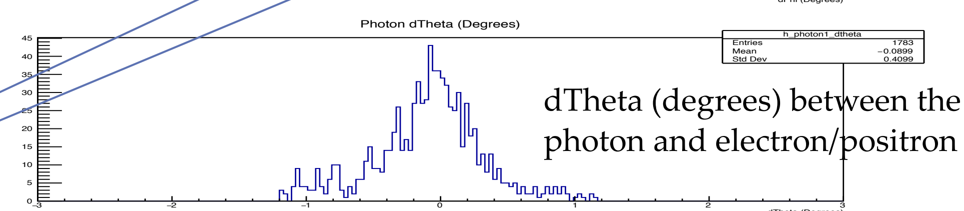
*Application of this technique results in a stronger J/Psi mass signal as well as cleaner quasi-real photoproduction distributions

*There are two sources of radiation that can originate in the target or outside of the solenoid field.





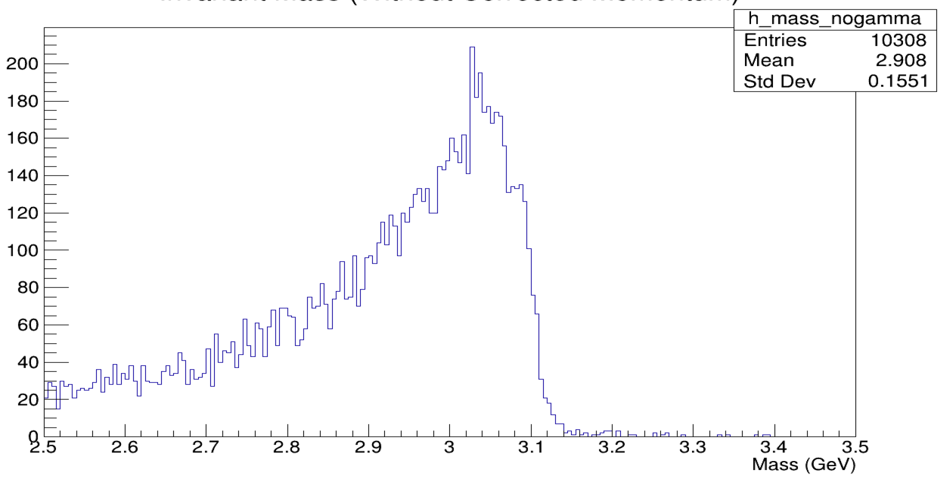




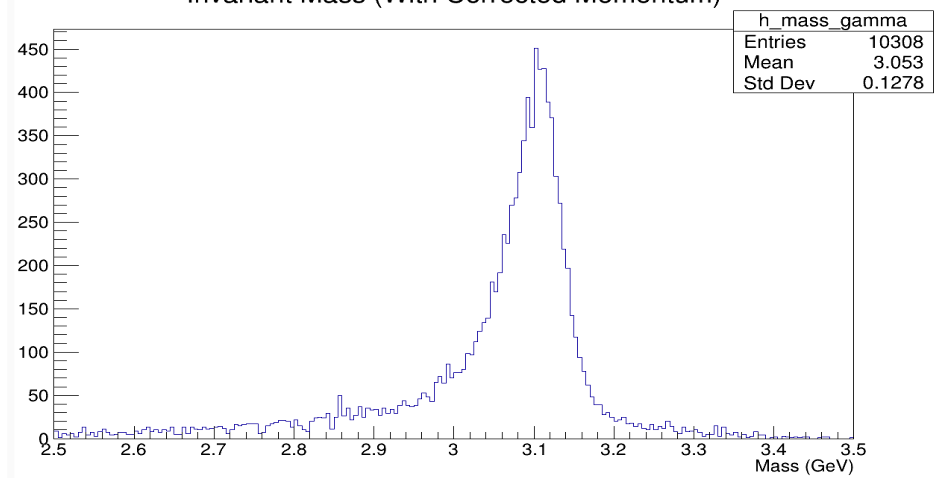
Effects of Radiative Photons On J/Psi Reconstruction (continued)

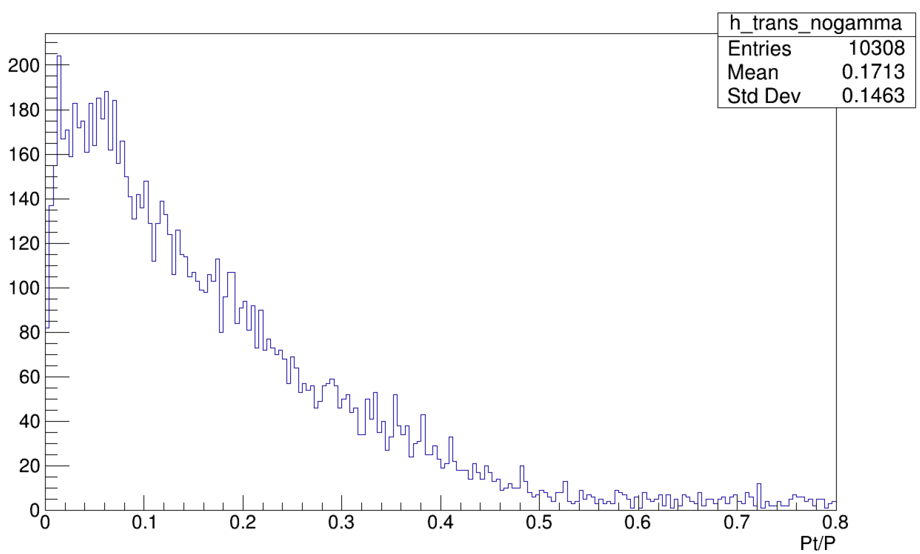
Events with a photon associated with the energy loss of an electron show a clear difference before and after correcting for the momentum. The invariant mass's quality is improved. The transverse missing momentum fraction, a property of quasi-real photoproduction, has a sharper distribution.

Invariant Mass (Without Corrected Momentum)

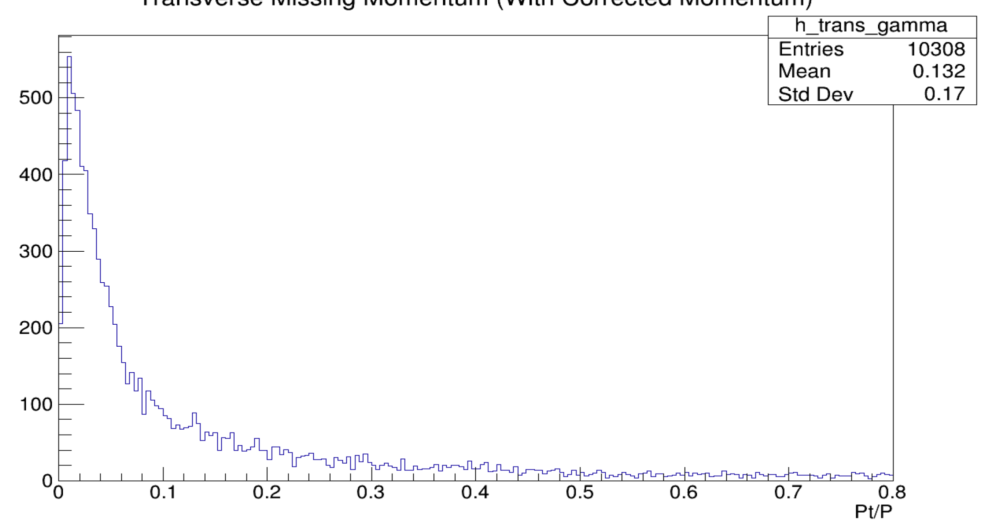


Invariant Mass (With Corrected Momentum)

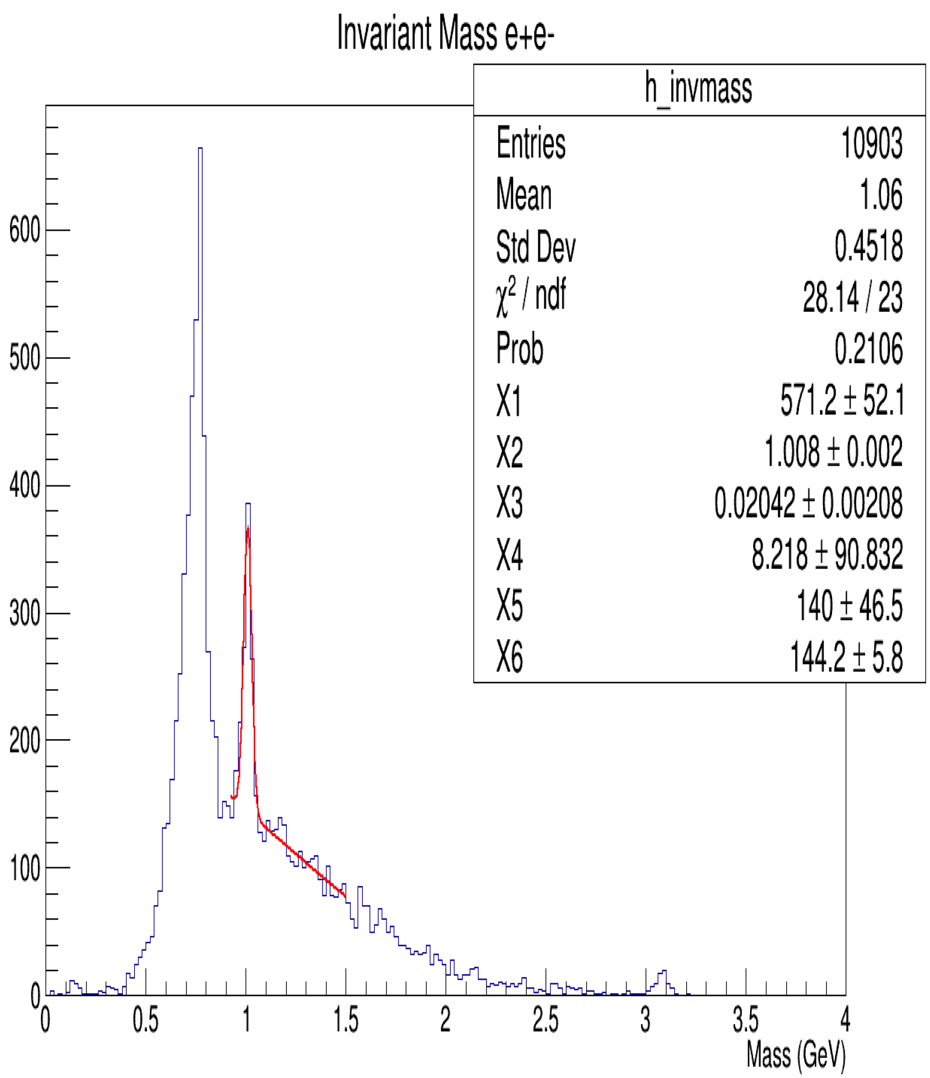


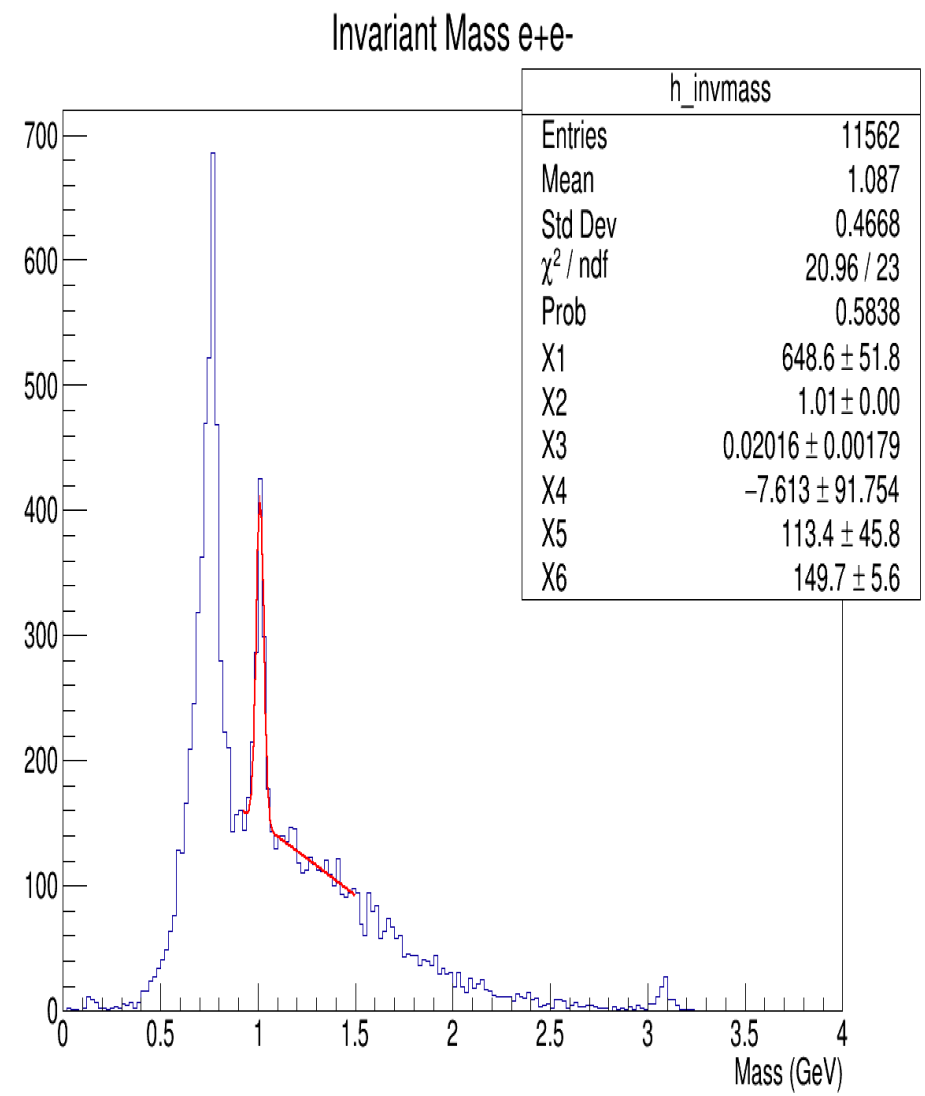


Transverse Missing Momentum (With Corrected Momentum)



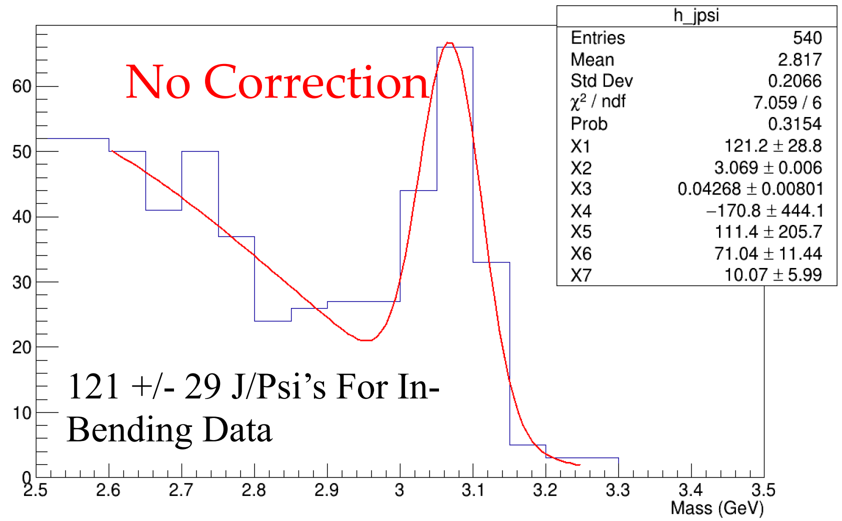
Un-Corrected vs. Corrected Radiated Energy Loss (With Same PID & Exclusivity Cuts) For Phi Resonance

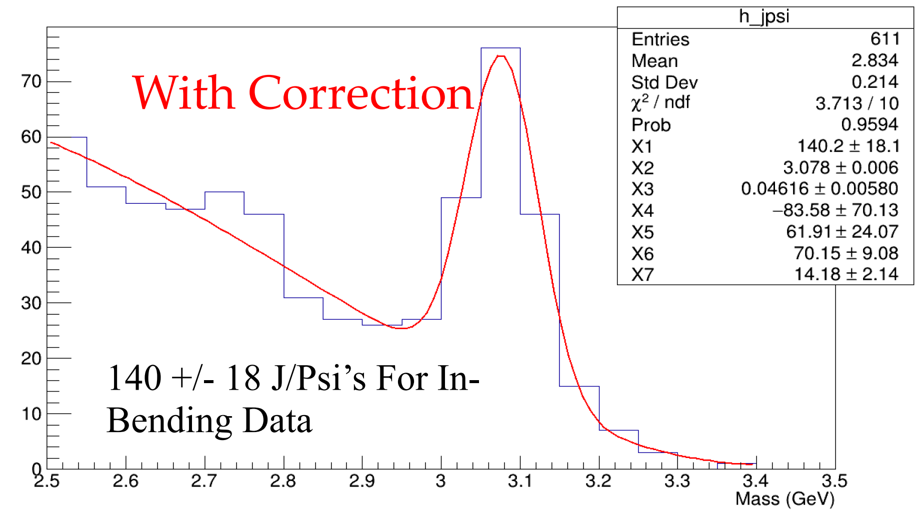


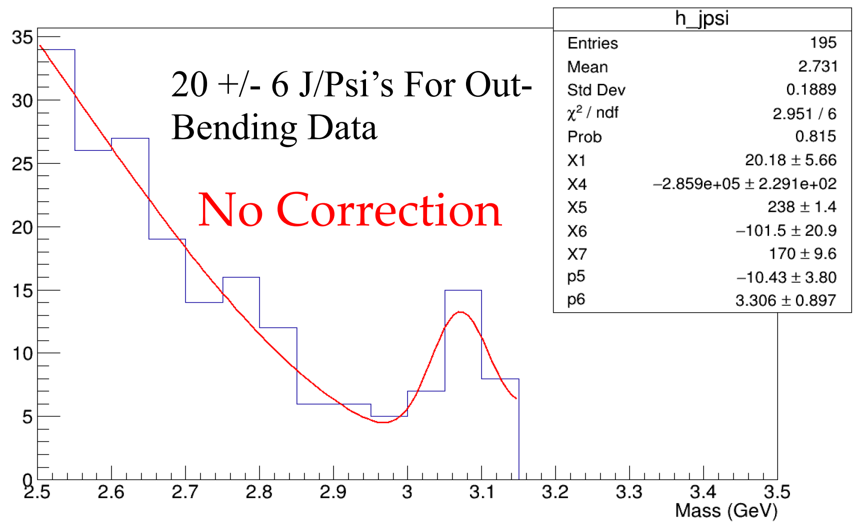


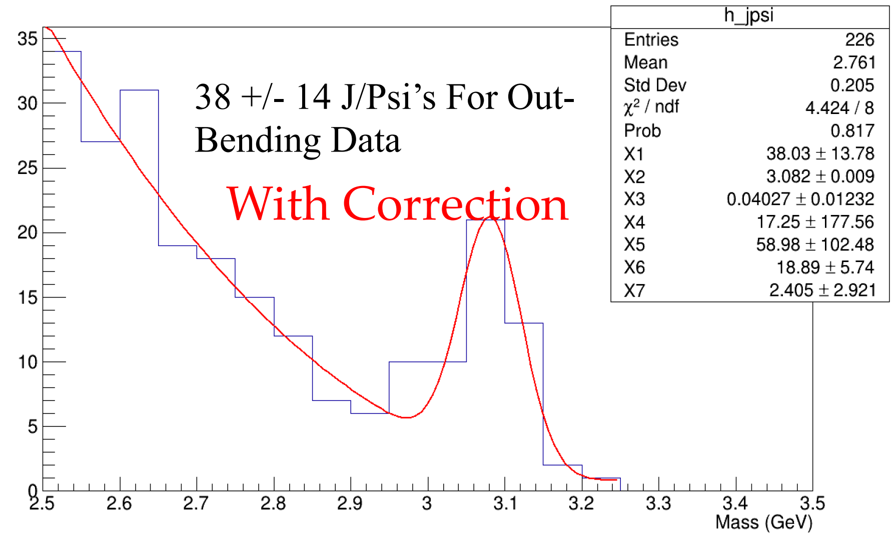
Un-Corrected vs. Corrected Radiated Energy Loss (With Same PID & Exclusivity Cuts) For J/Psi Peak

Events with a photon associated with the energy loss of an electron also show improvements in the strength of vector meson reconstruction in RG-A data, including Phi.





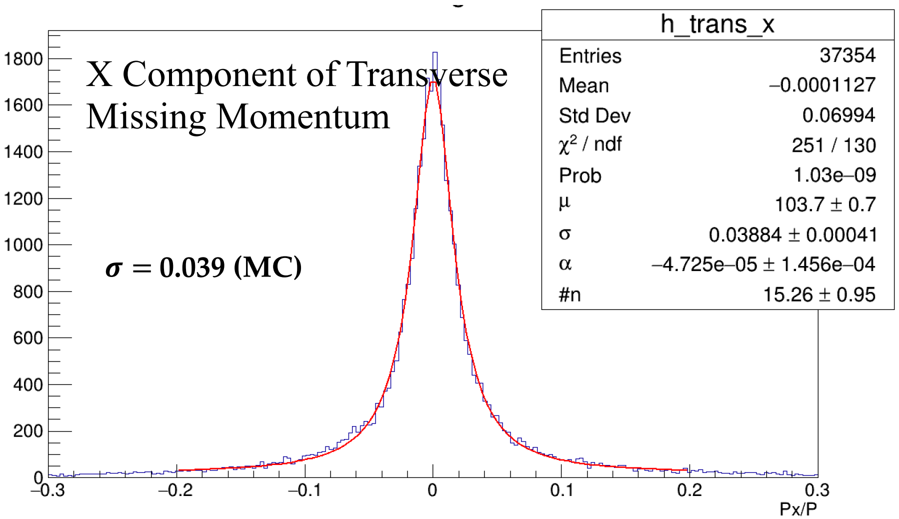


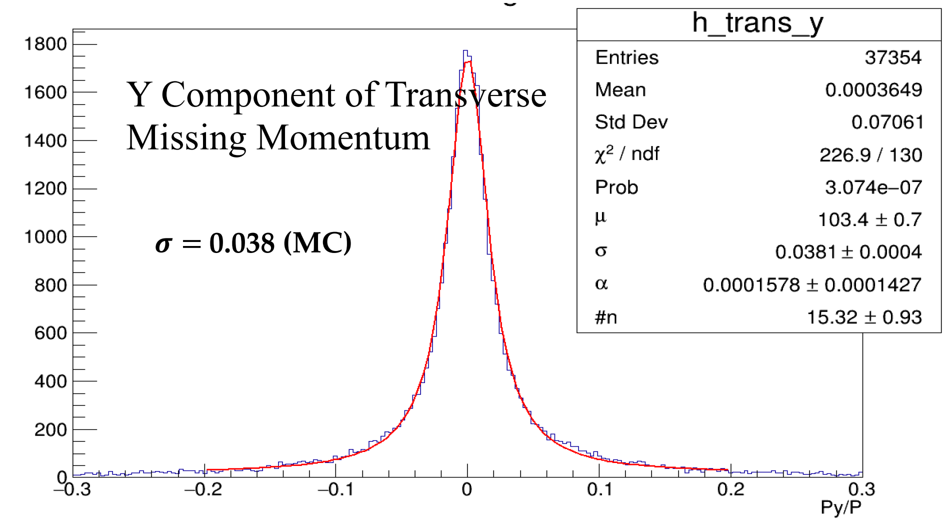


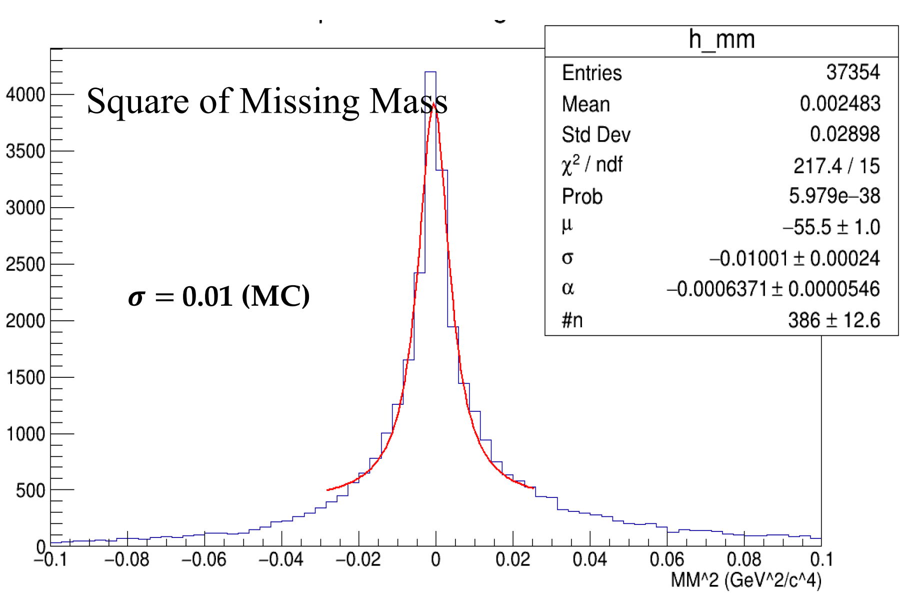
Breakdown Of Radiative Photon Events (Mass > 2.5 GeV)

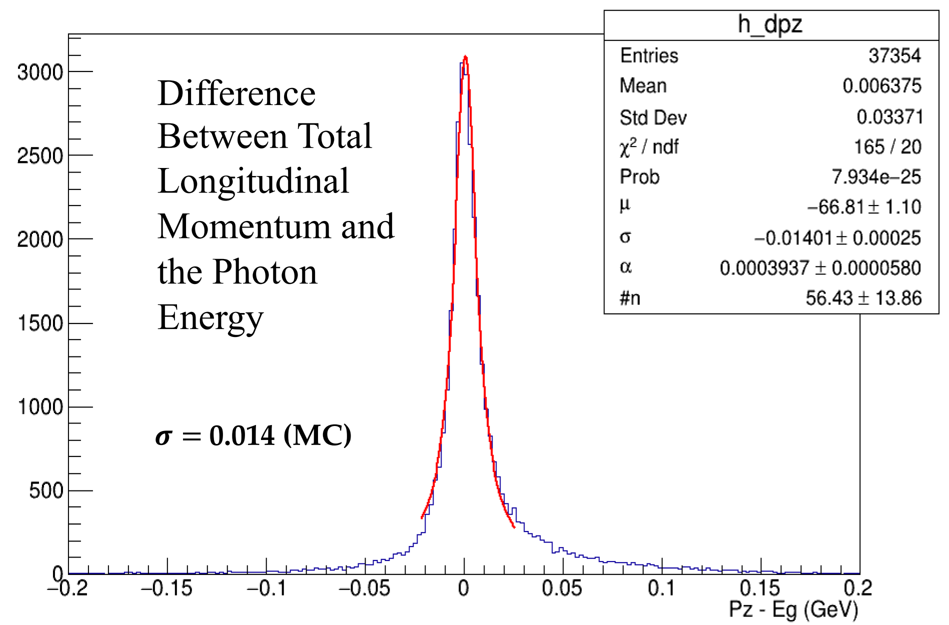
% of Events	In-Bending Events	Out-Bending Events
Originate From Electron	12%	14%
Originate From Positron	13%	10%
Neither	75%	75%

1-Dimensional MC Quasi-Real Photoproduction



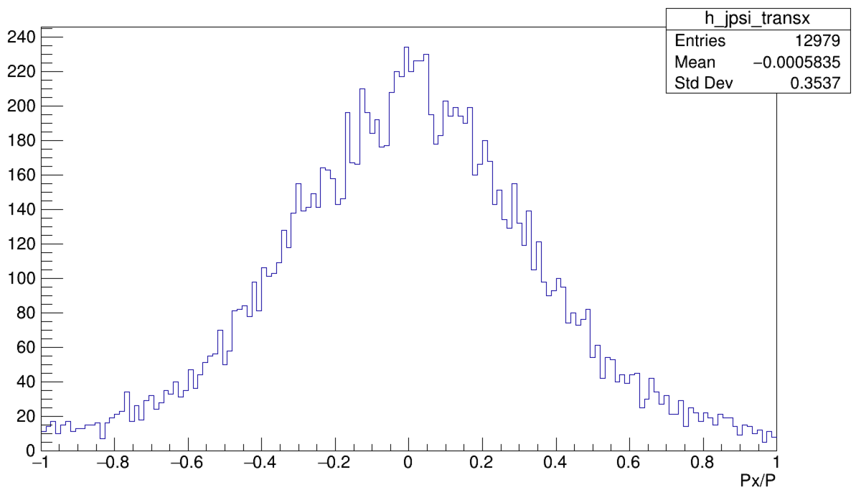


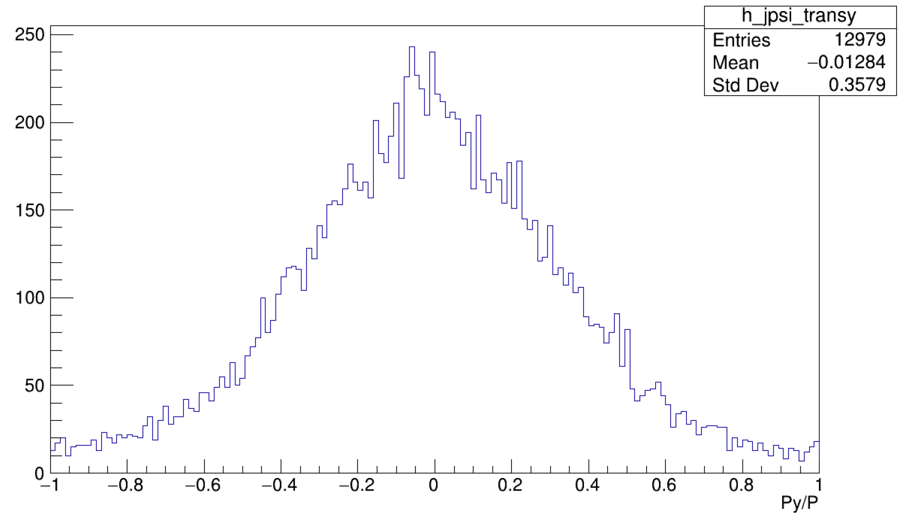


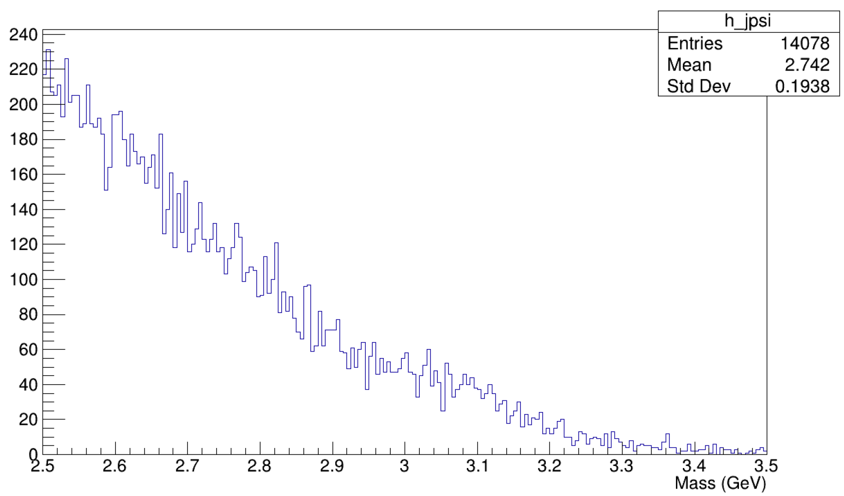


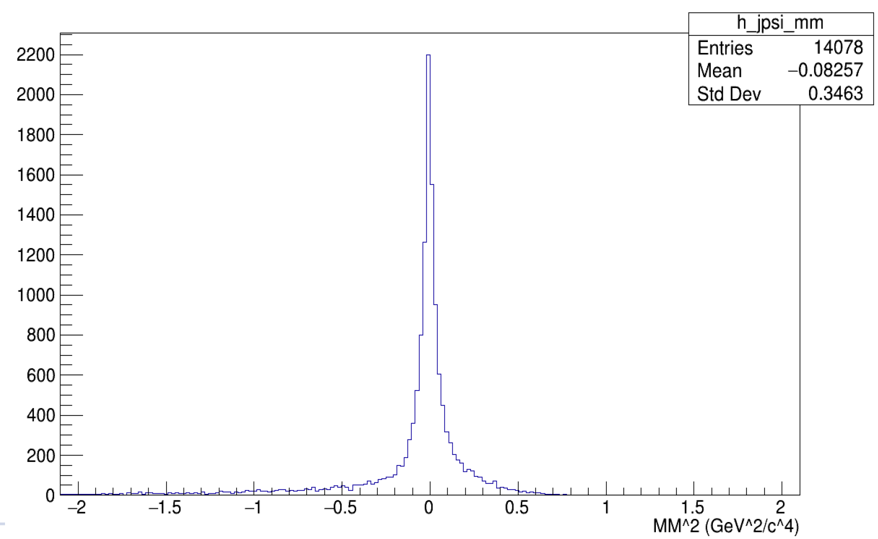
Studying RG-A Quasi-Real Photoproduction

- **Before applying exclusivity cuts, the first step is to apply cuts on photon energy (> 8.21 GeV) , invariant mass (> 2.5 GeV), and opposite sectors for the e+e- pair.**



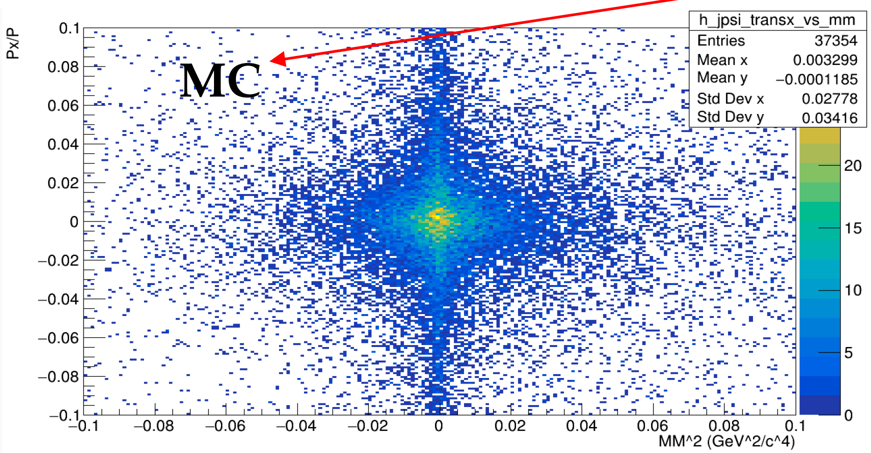


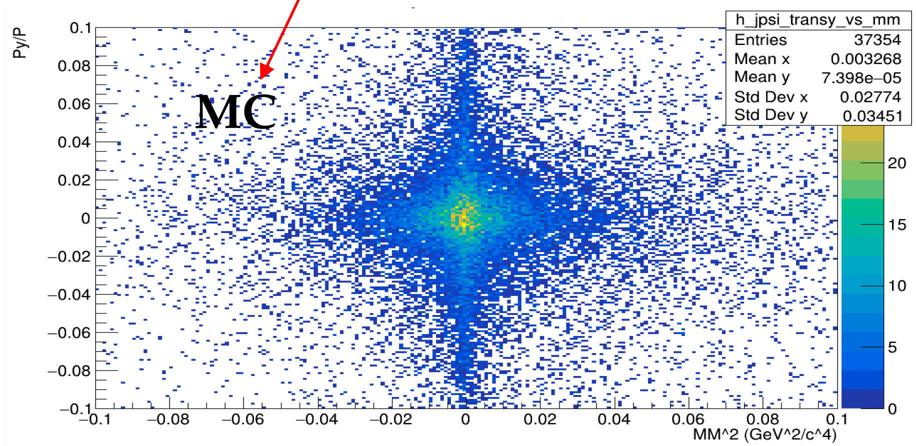


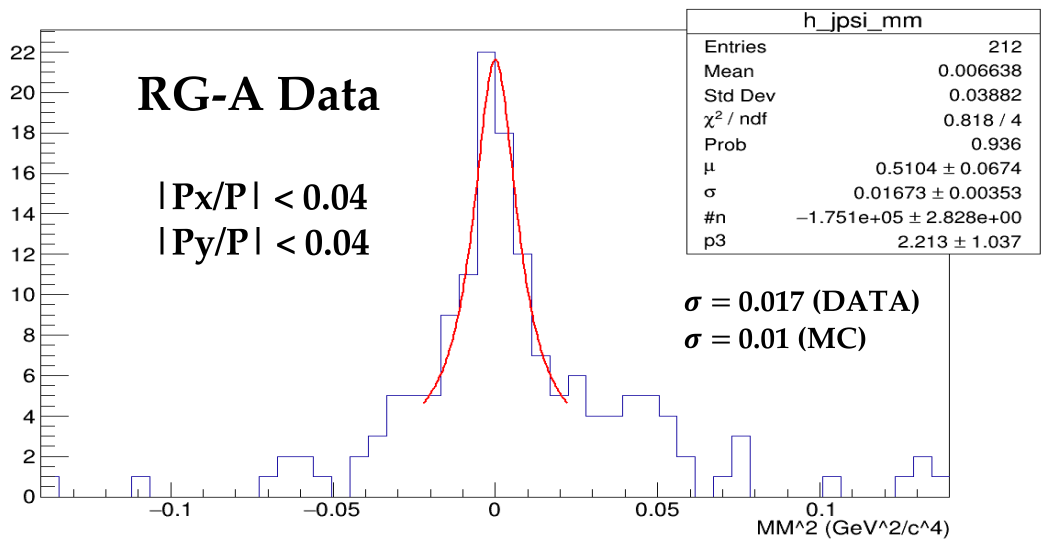


Studying The Square Of The Missing Mass In RG-A Data

Because MM^2 shows little correlation with both Px/P & Py/P in MC, cuts can be applied to Px/P and Py/P to freely study MM^2 in Fall 2018 RG-A data.

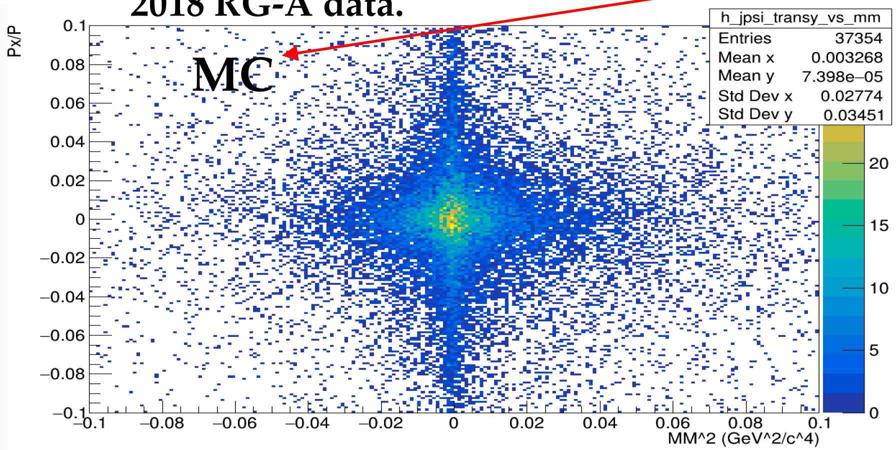


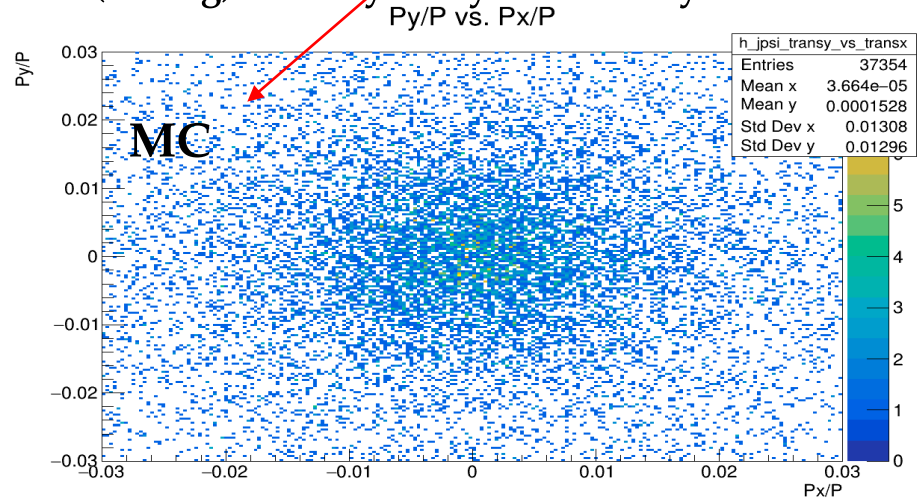


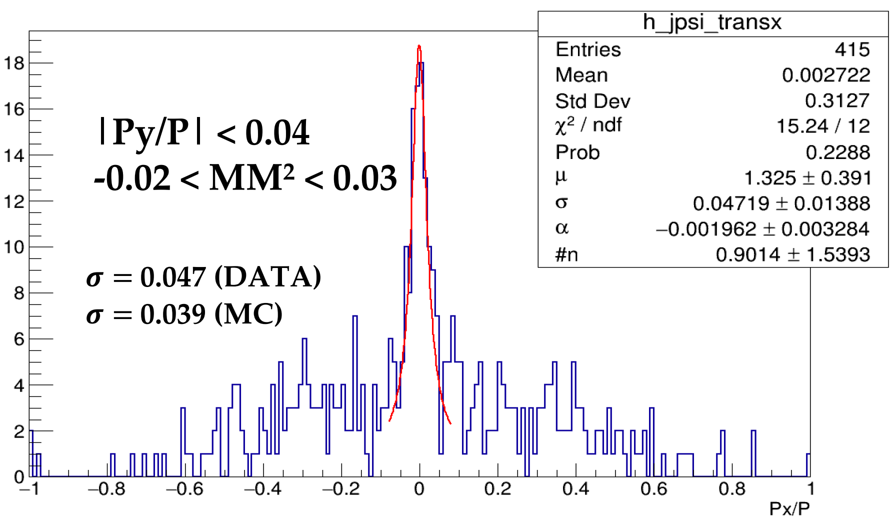


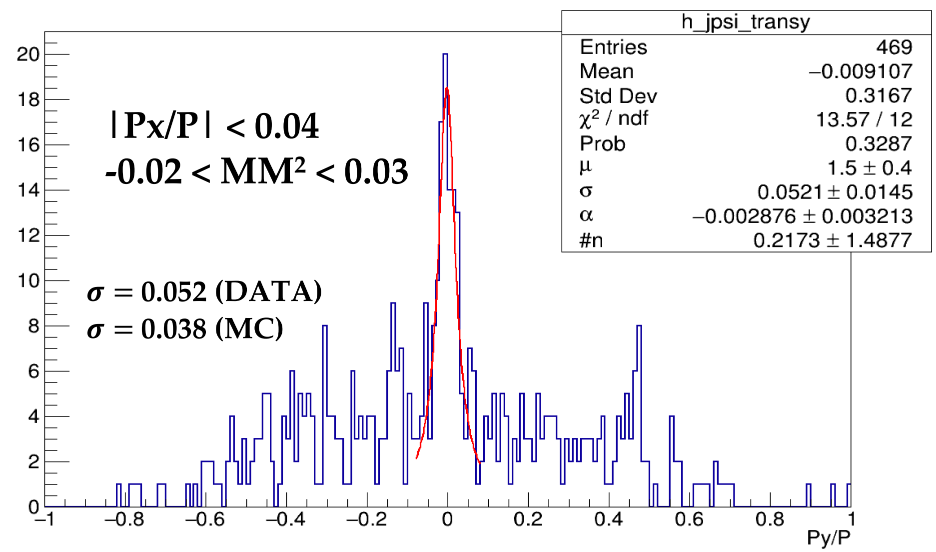
Studying Px/P and Py/P In RG-A Data

Because both Px/P & PyP show little correlation with both MM^2 and their perpendicular component in MC, cuts can be applied to MM^2 and (Pz - Eg) to freely study Px/P and Py/P in Fall 2018 RG-A data.



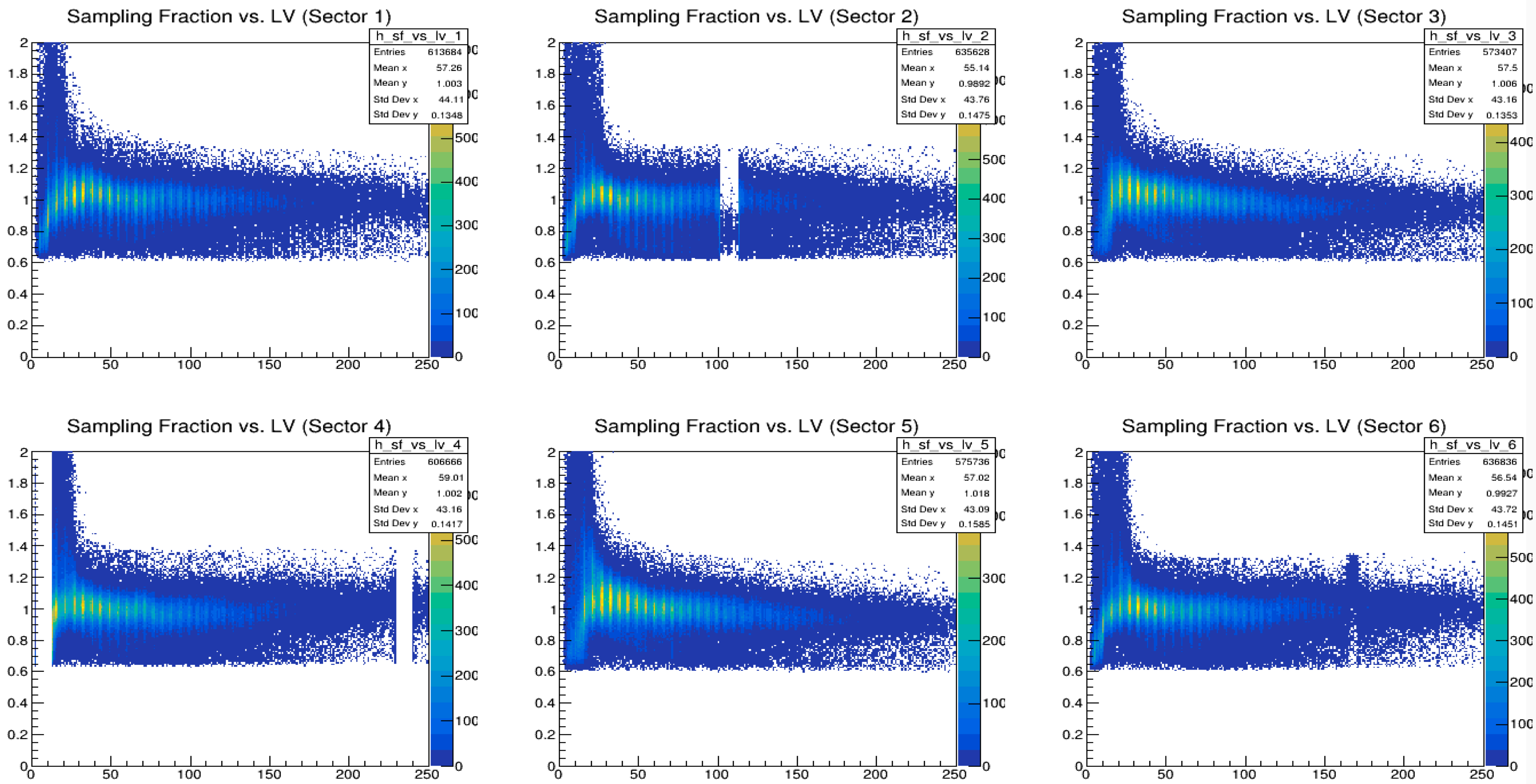




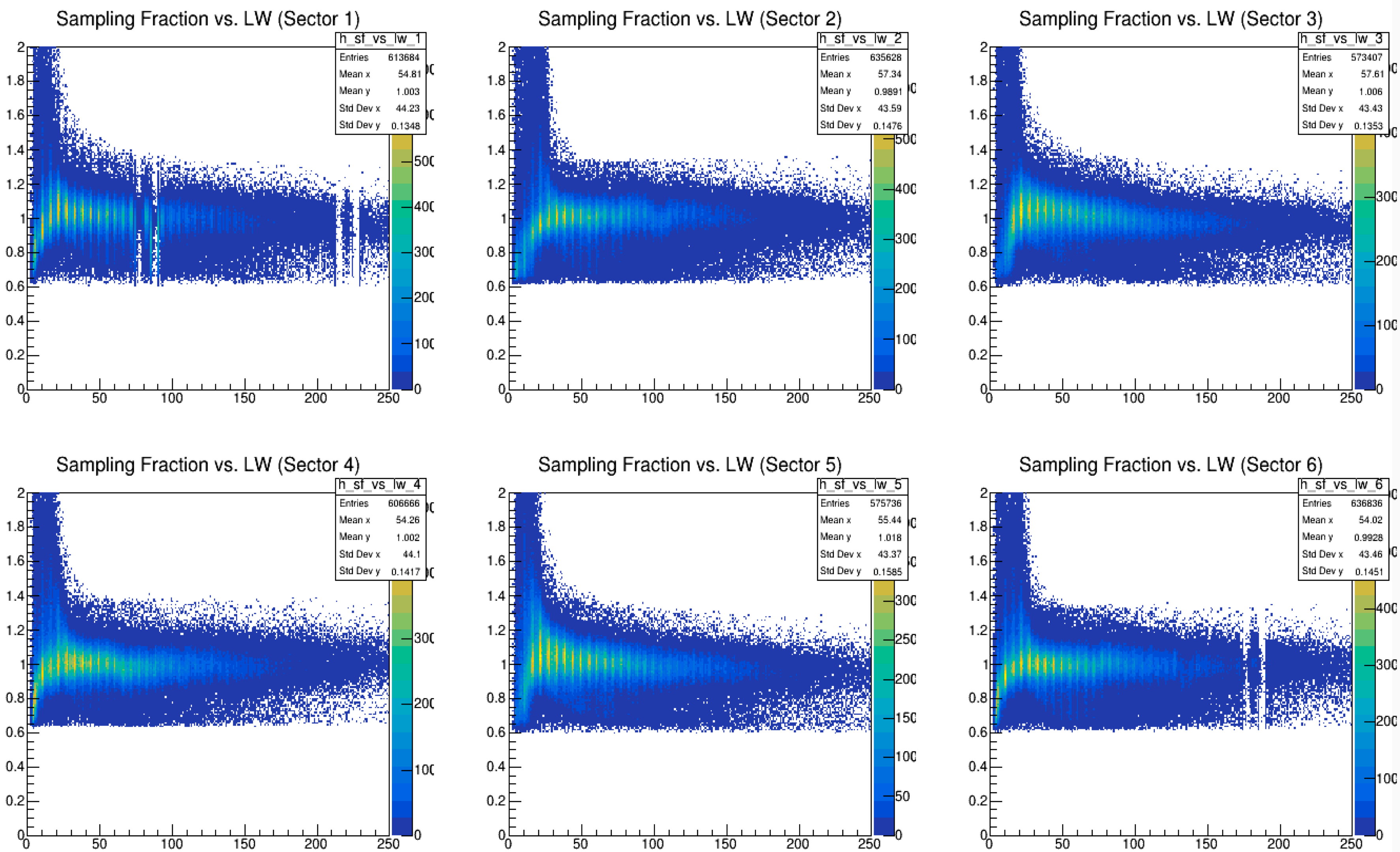


Fiducial Volume Strategy

For the selection of electrons and positrons, fiducial cuts will be applied to regions of PCAL. This strategy follows the procedure discussed in the Deep Process Working Group that will be standardized for the RG-A common analyses. The cuts used are: PCAL LV > 14 cm & PCAL LW > 14 cm.

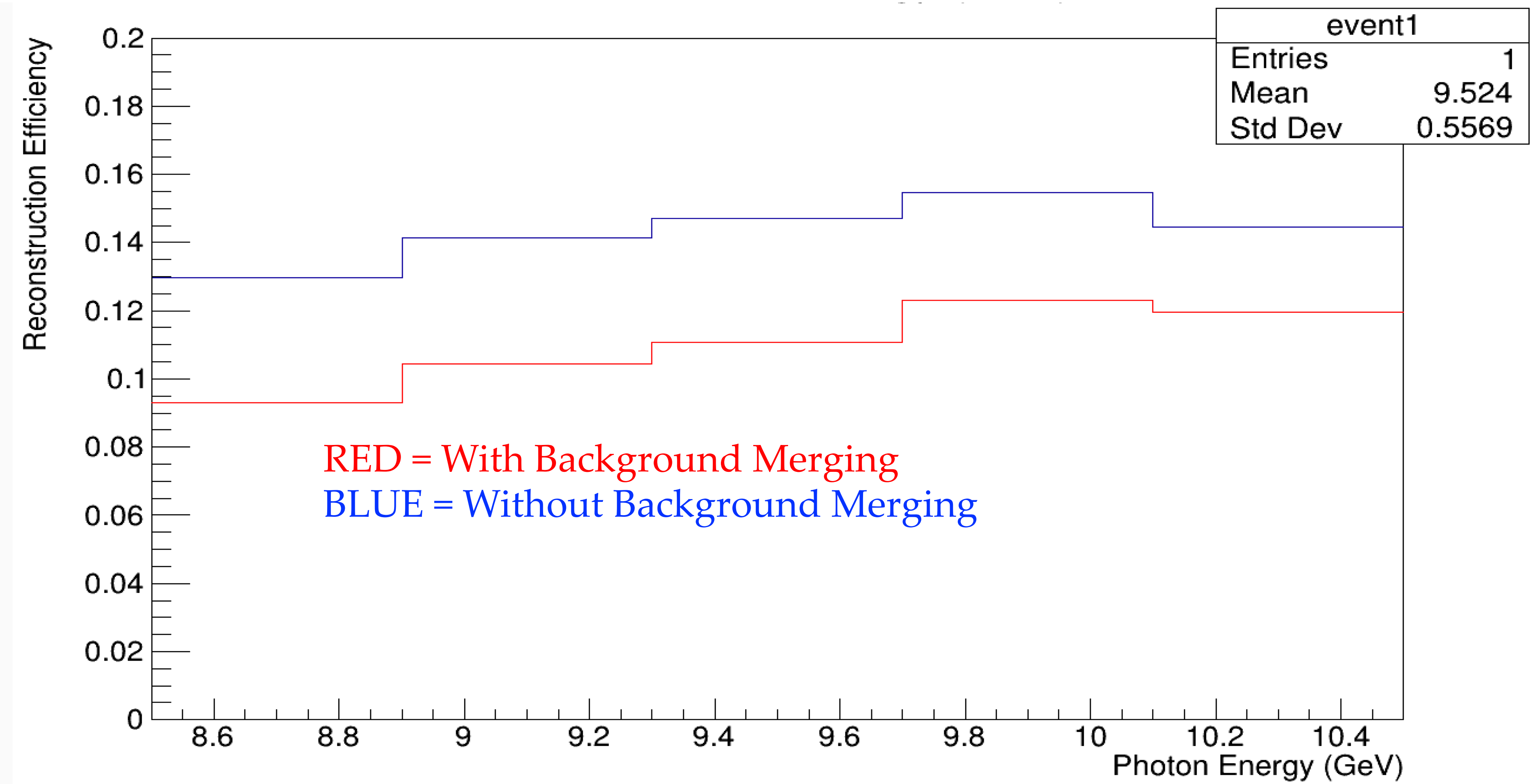


Fiducial Volume Strategy (continued)

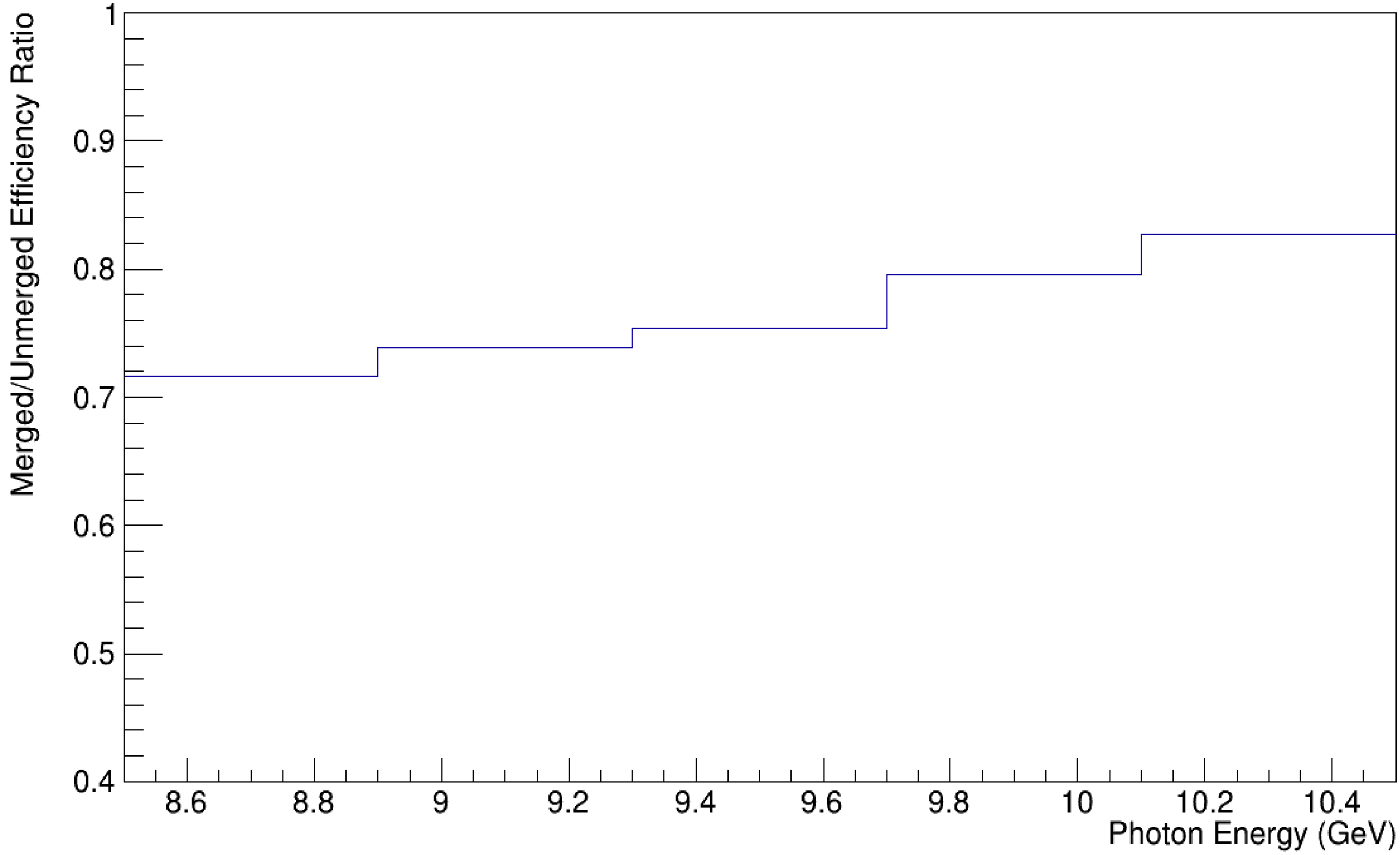


J/Psi Reconstruction Efficiency

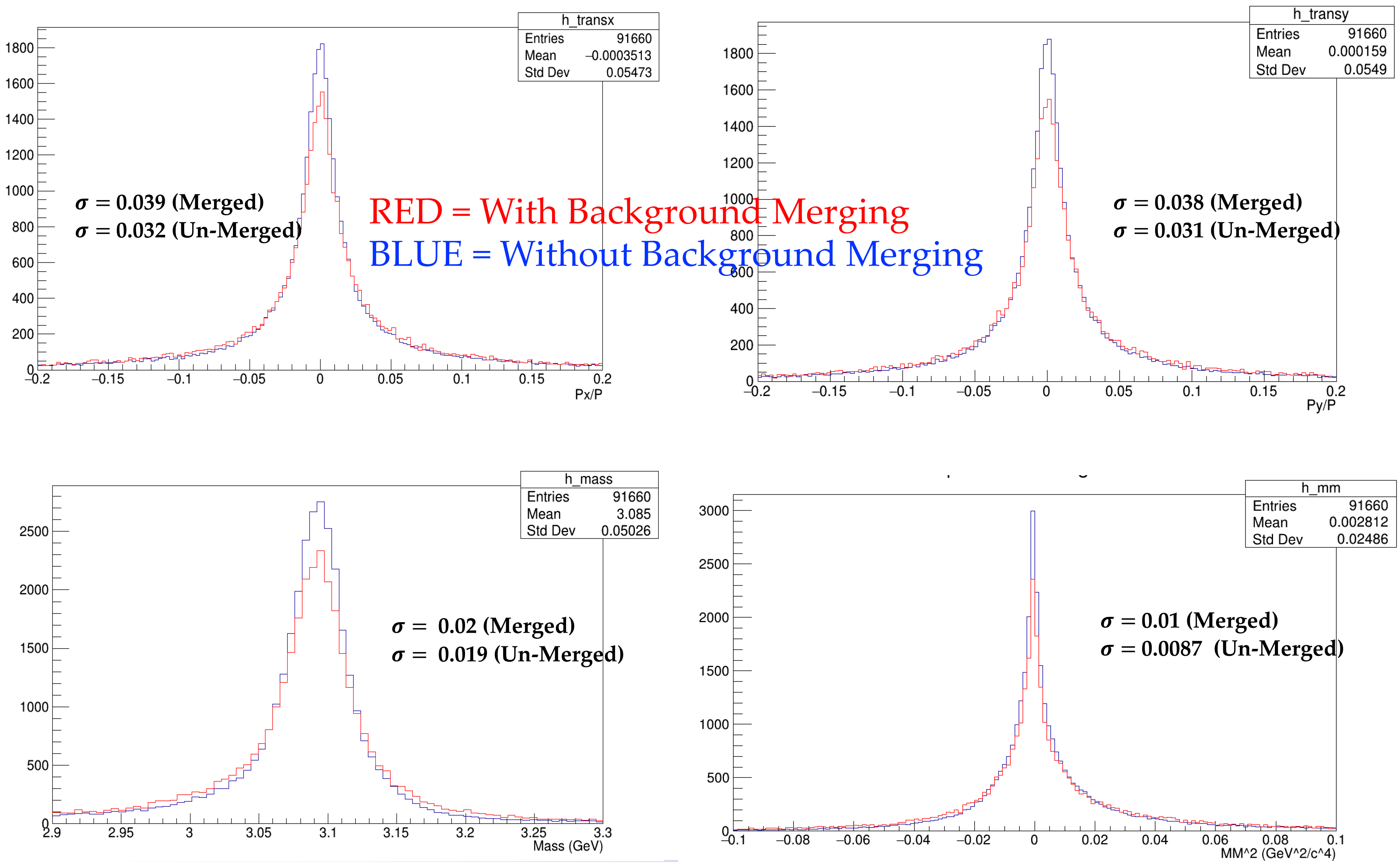
Studies have begun using the latest background merging algorithm (V9) along with the latest version of GEMC (4.4.0).



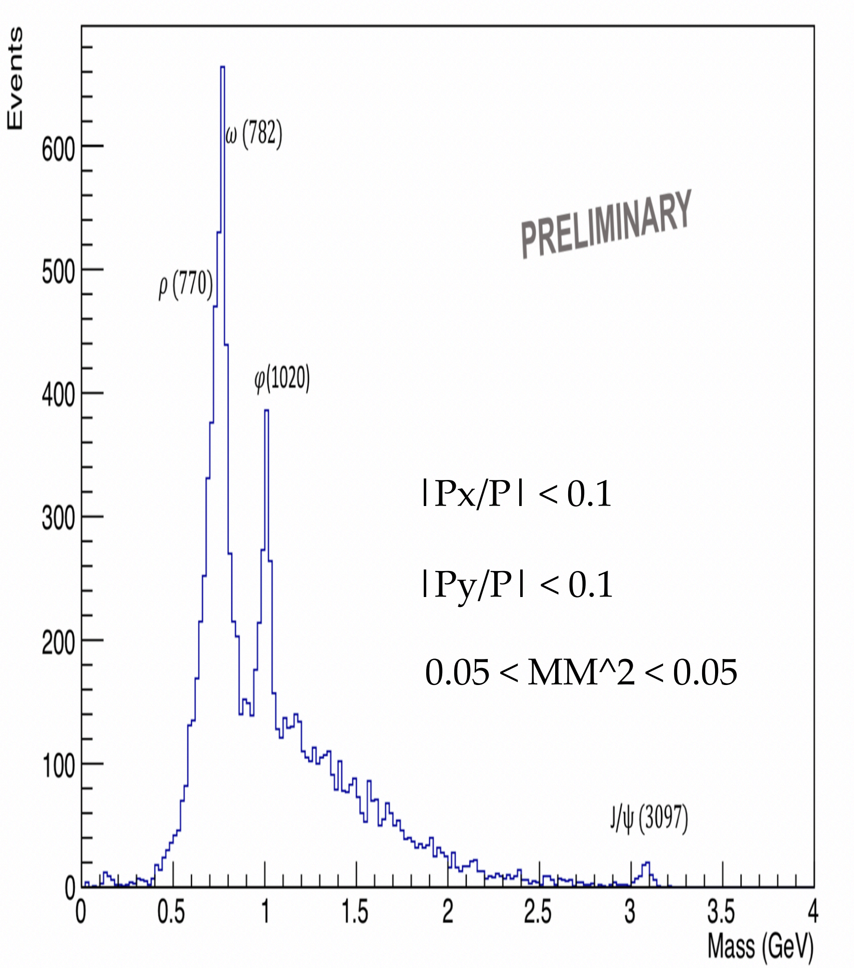
Un-Merged vs. Merged Reconstruction Efficiency Ratio

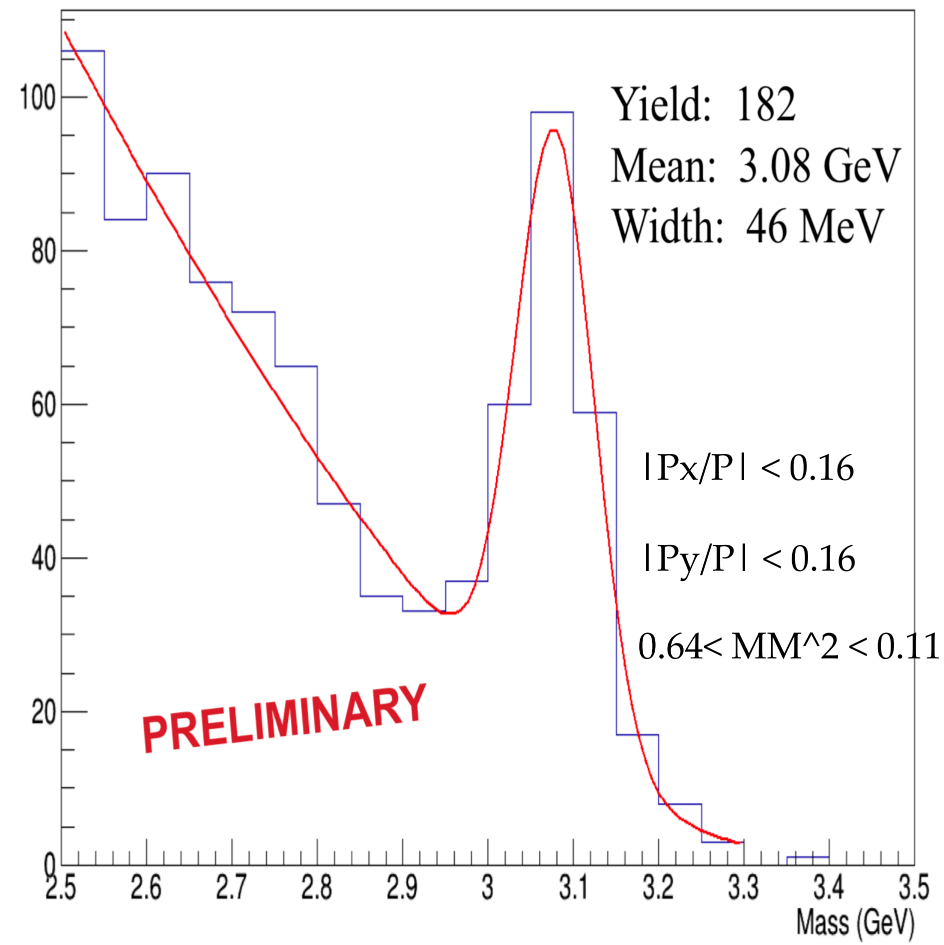


Quasi-Real Photoproduction (J/Psi) With Background Merging



Invariant Mass (In-Bending & Out-Bending Datasets)

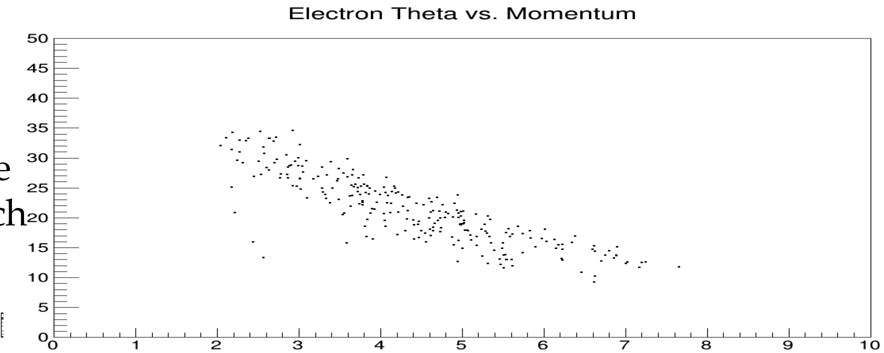


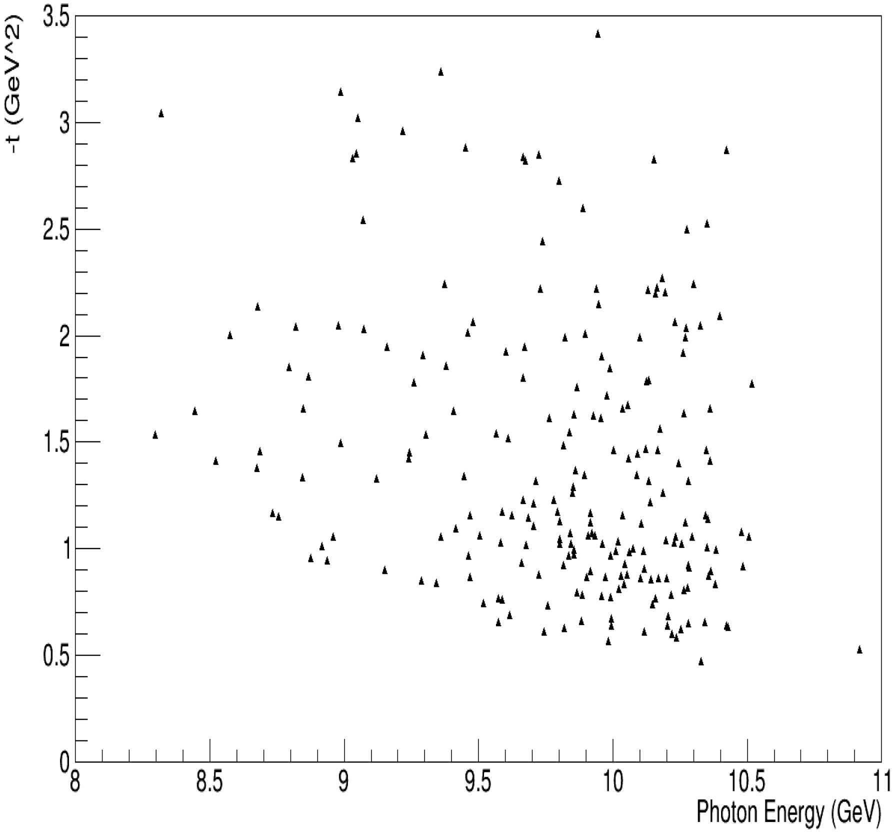


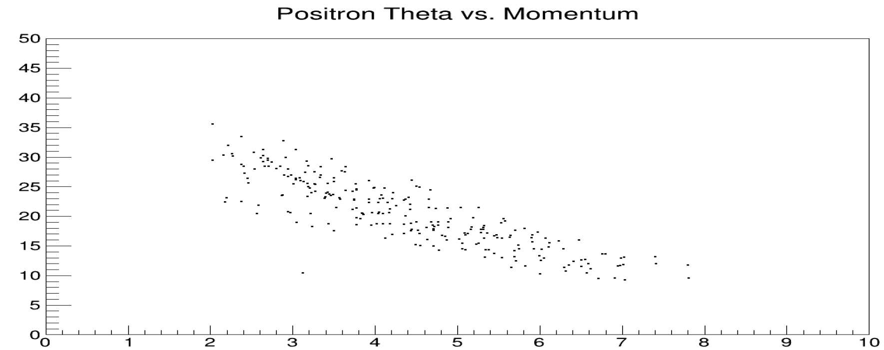
Note: These two distributions do not have the same exclusivity cuts and momentum cuts. The cuts for the full spectrum are tighter just to highlight the lower mass vector mesons.

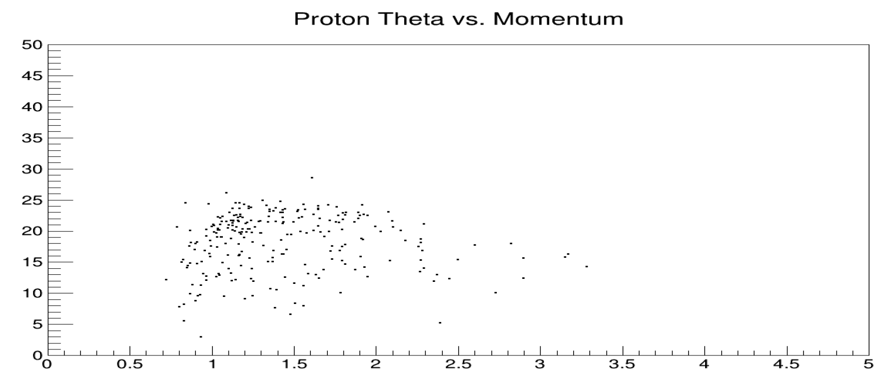
Kinematics (In-Bending & Out-Bending Datasets)

Each of the events in these distributions were selected under the J/Psi peak. The kinematics of the final-state particles are comparable to MC. With the addition of Spring data processing, J/Psi events in the relevant phase space will be high enough to extract cross sections in each bin.









Next Steps

- Analysis framework has become quite advanced
- With the Fall 2018 dataset, there is a sharp and clean J/Psi peak with 182 events.
- High statistics from the completion of the RG-A pass1 data processing (Spring 2018 & Spring 2019) will allow for the measurements of cross sections and the forward-backward asymmetry.
- Acceptances and normalization using Bethe-Heitler MC simulations will be completed with latest software releases and background merging algorithm.
- Work is being documented for a future analysis note

Thank you!