J/Ψ in the di-muon channels

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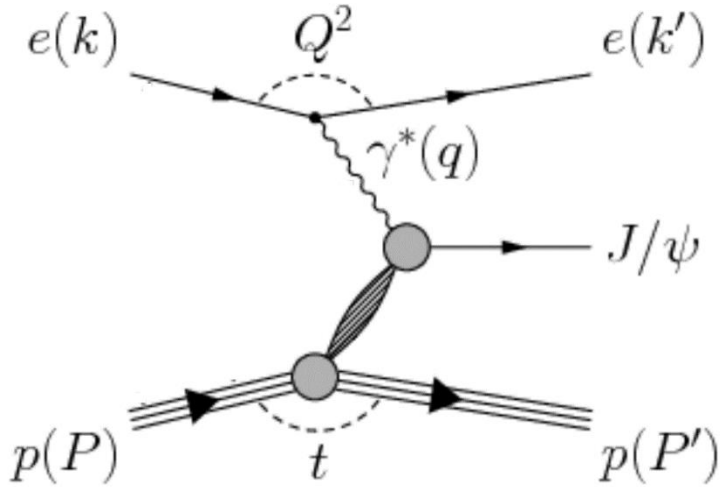
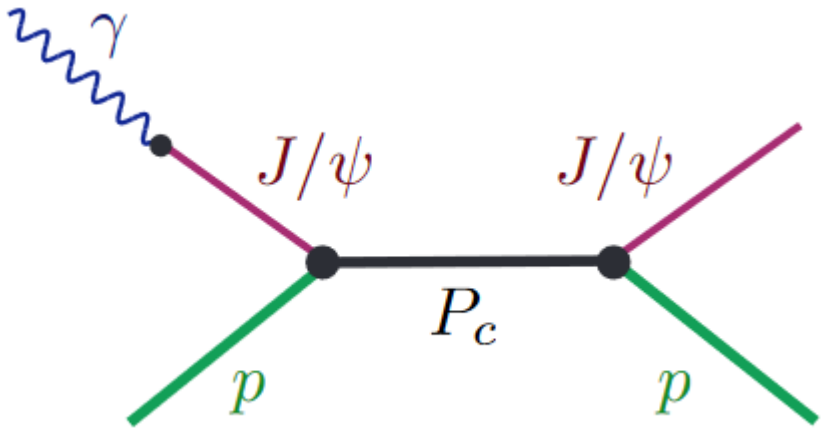
Experiment Overview

$$ep \rightarrow (e')\mu^+\mu^- p$$
$$ed \rightarrow (e')\mu^+\mu^- p(n_{spec})$$

- The electron beam produced by CEBAF scatters with a liquid hydrogen or deuteron target through the exchange of a quasi-real photon $Q^2 \sim 0$.
- The proton and $\mu^+\mu^-$ pair produced in J/ψ decay are detected in the FD.
- Analyses based on chanser framework: **https://github.com/dglazier/chanser**



J/ψ quasi-real photoproduction

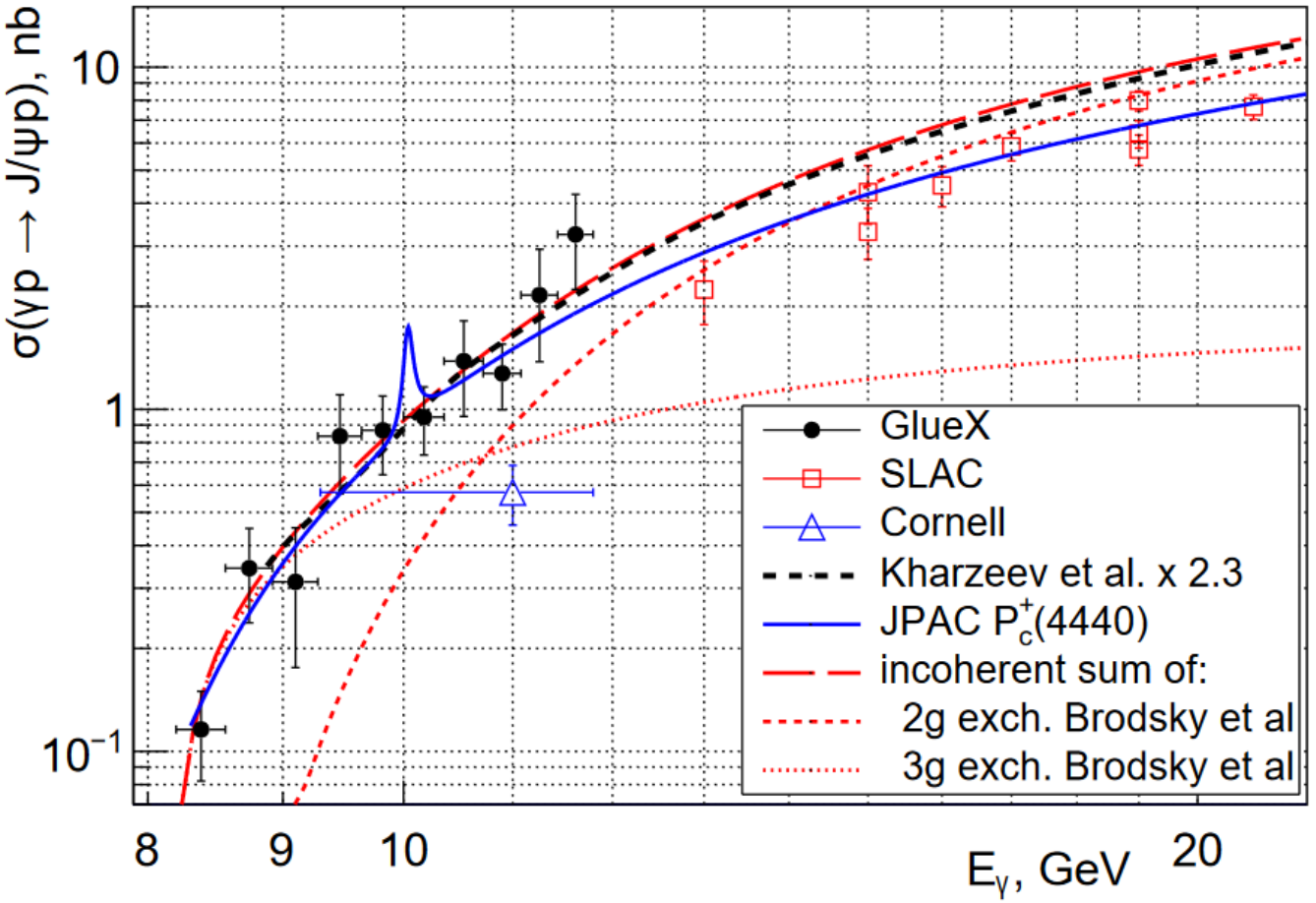


Feynmann diagram of P_c^+ pentaquark photoproduction.

J/ψ Near Threshold Photoproduction

- Measuring the total cross section as a function of photon energy allows us to study the J/ψ production mechanism [2].
- The total cross section can be related to J/ψ-p forward scattering via VMD which will allow to estimate the QCD trace anomaly that is a part of the proton mass decomposition.
- [3] predicts that the t dependency of the differential cross section is defined by a nucleon gluonic form-factor, for which a dipole form is assumed with $m_g^2 \approx 1\ GeV^2$ as:

$$F(t) \propto (1 - t/m_g^2)^{-2}$$

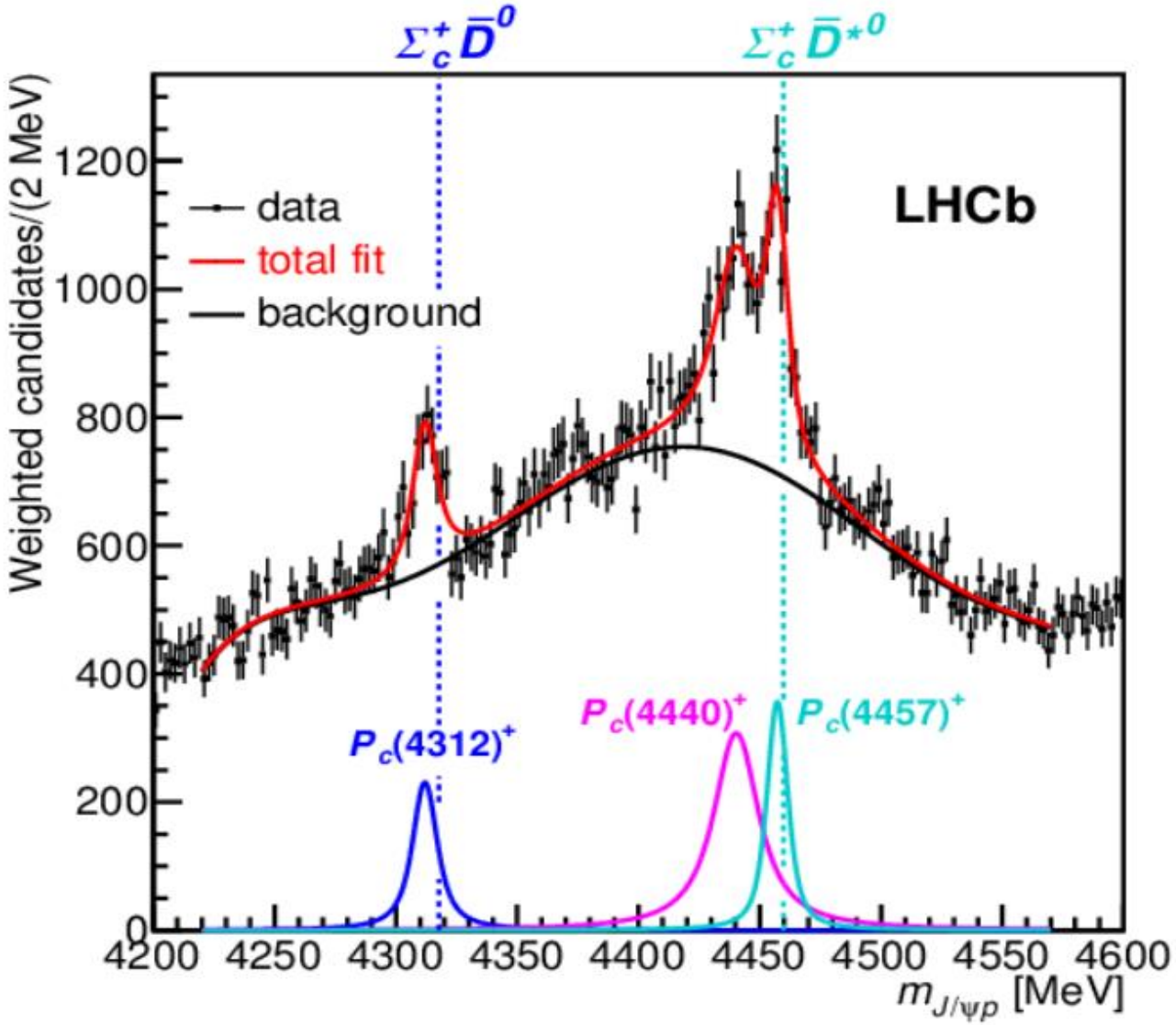


Measurements of the J/ψ total cross section as a function of the photon beam energy and theoretical predictions scaled to GlueX data [1].

[1] A. Ali, *et. al.* (GlueX Collaboration), *Phys. Rev. Lett.* **123,** 072001 (2019).
[2] S. Brodsky, E. Chudakov, P. Hoyer, J. Laget, *Phys. Lett. B.* **498**, 23 (2001).
[3] L. Frankfurt, M. Strikman, *Phys. Rev. D.* **66**, 031502 (2002)

P_c^+ resonances with CLAS12

- Different theoretical models for the structure of the P_c^+ pentaquarks favor different decay mechanisms.
- Should be able to place upper limits on the branching fraction $\mathrm{B}(P_c^+ \rightarrow \mathrm{J/\psi\ p})$.

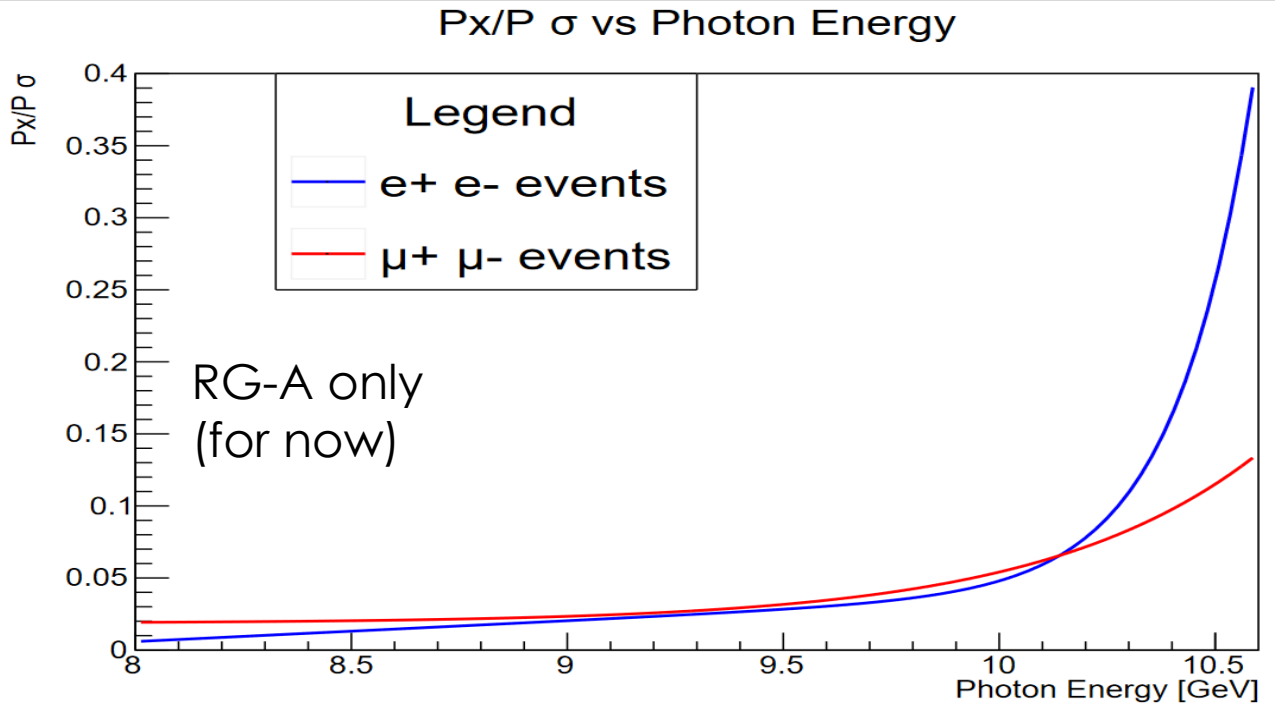


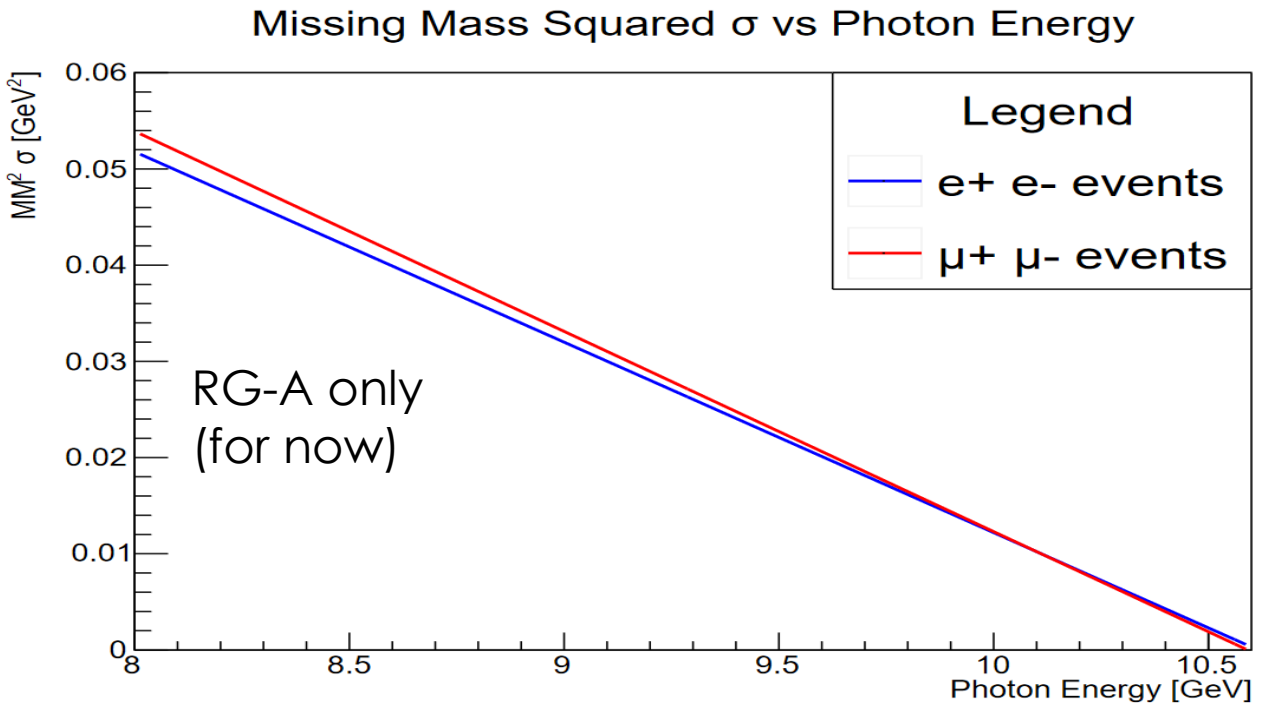
The J/ψ p invariant mass distribution measured at the LHCb. Taken from:

R. Aaij, *et. al.* (LHCb Collaboration), *Phys. Rev. Lett.* **122,** 22 (2019).

Initial Event Selection

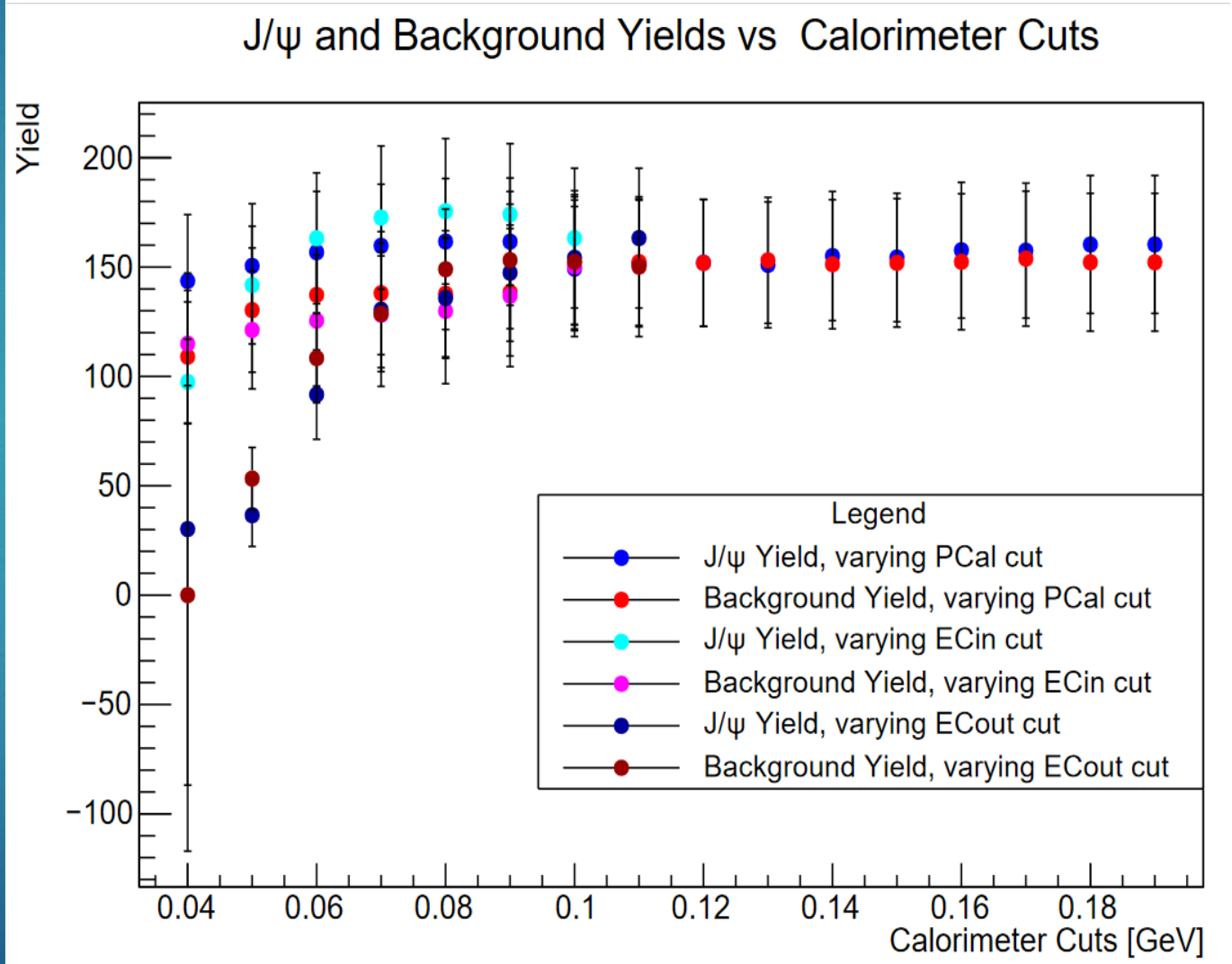
- To select events in quasi-real photoproduction regime we can minimize:
  - The difference between the initial and scattered electron four-momentum, Q^2
  - The scattered electron transverse momentum fractions in the x and y components, $|\frac{Px}{P}|$ and $|\frac{Py}{P}|$.
- Similarly, we want the missing mass close to the mass of the scattered electron (which is effectively 0).
- The widths of these distributions can be parametrised as a function of the photon energy.





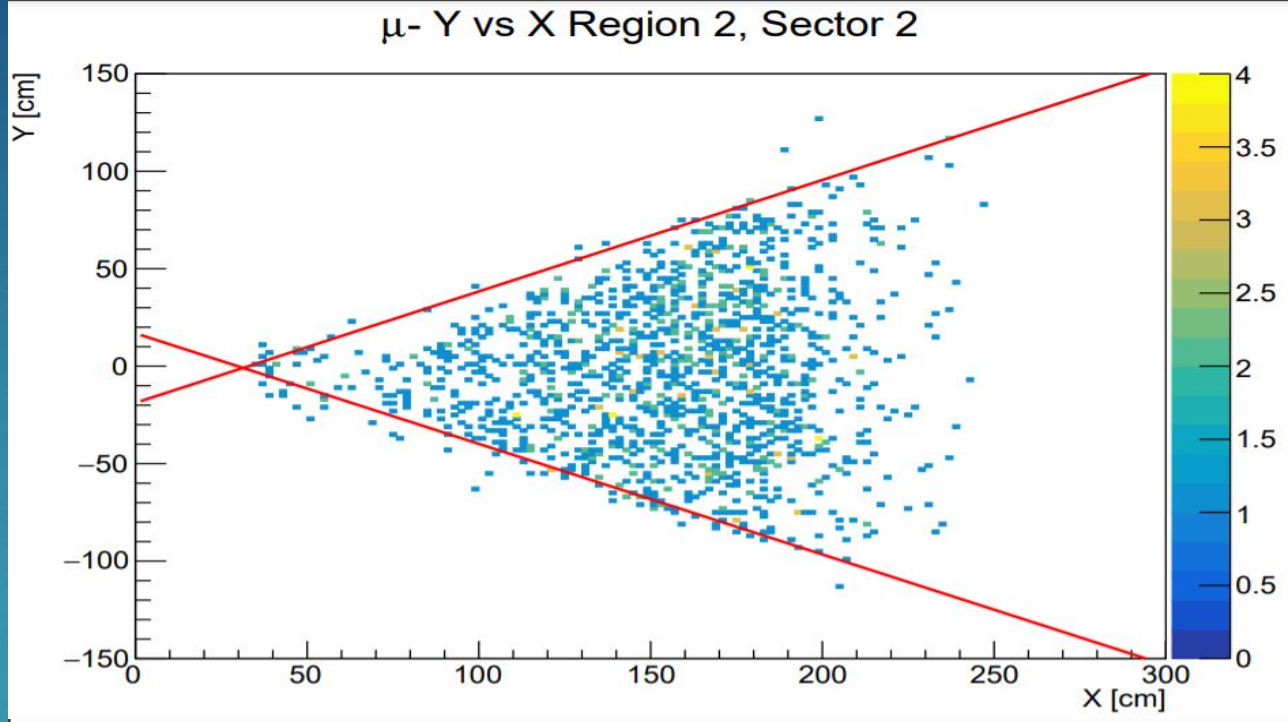
Muon Identification

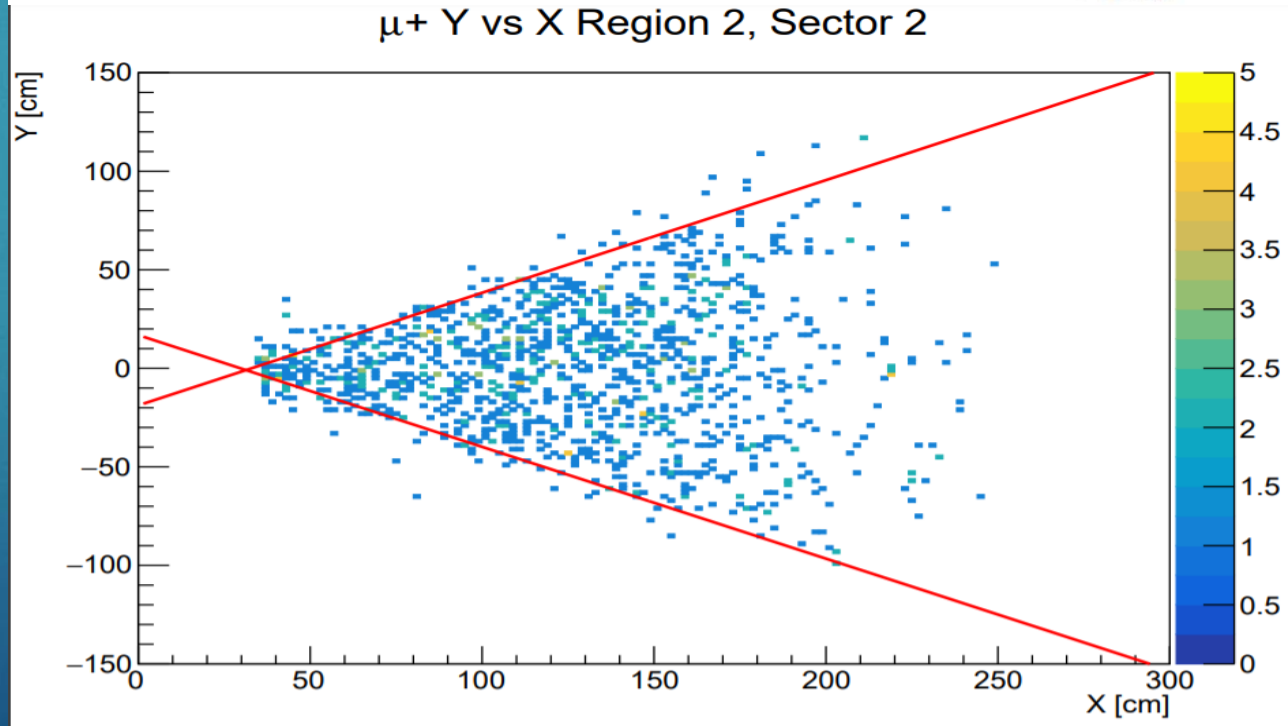
- Muon candidates are minimum ionizing particles and are therefore selected based on their energy deposition in the calorimeters.
- Use Cuts on the energy deposition as:
  - PCAL<60 MeV
  - ECin<80 MeV
  - ECout<110 MeV
- 60 MeV in the PCAL is the minimum requirement for electrons, and J/ψ doesn't decay to $\pi^+\pi^-$.



DC Fiducial Cuts

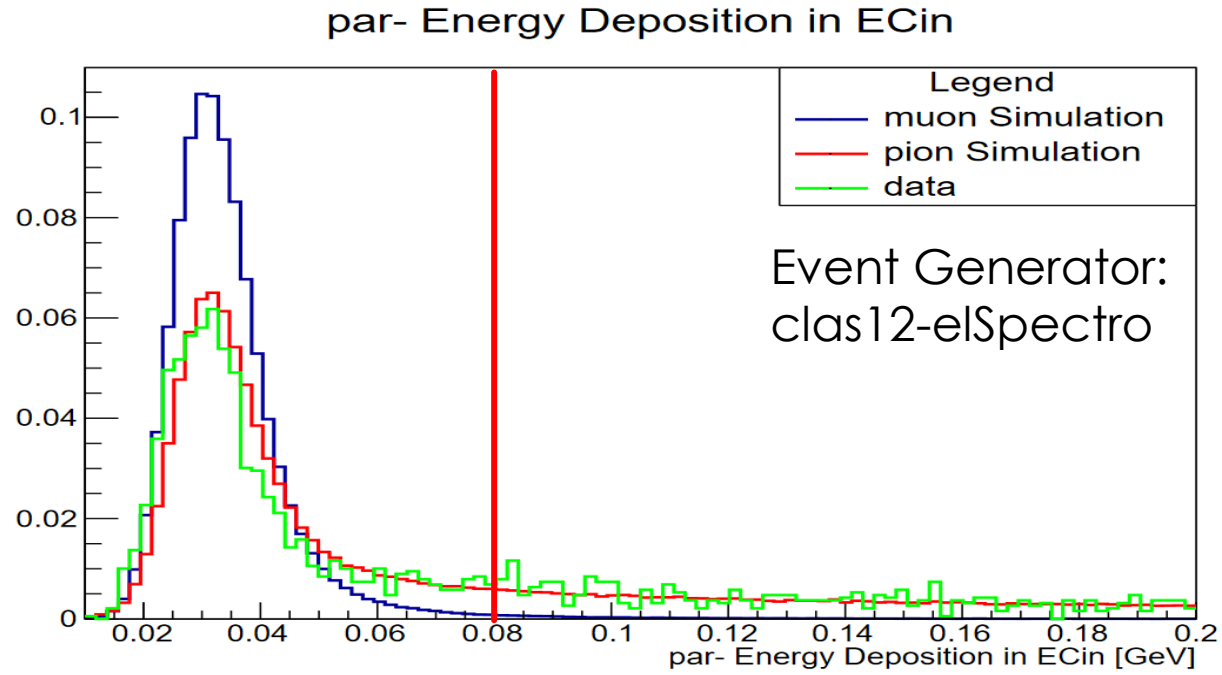
- Cuts are made on the fiducial region of the DC by removing events close to the edge of the detector.
- Here we use the parametrizations defined in the RG-A analysis note for electrons.
- These muon fiducial cuts are still being refined.

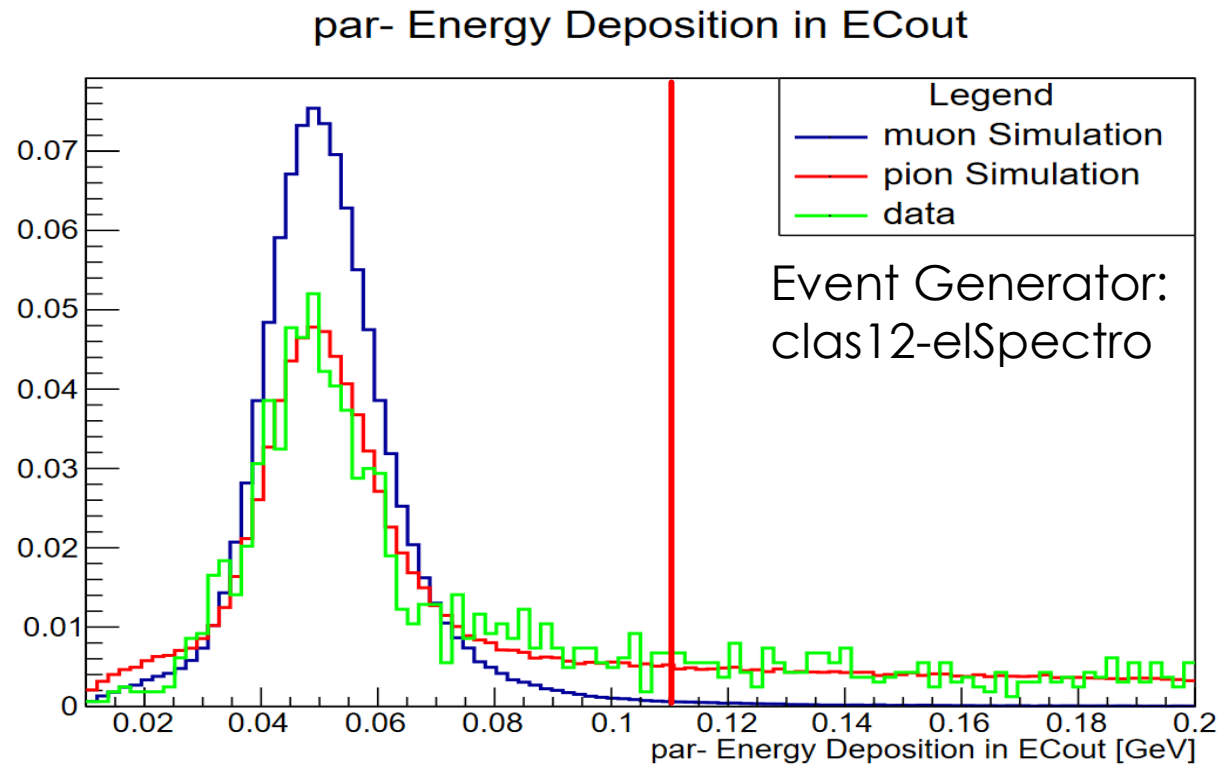




Muon ID Refinement

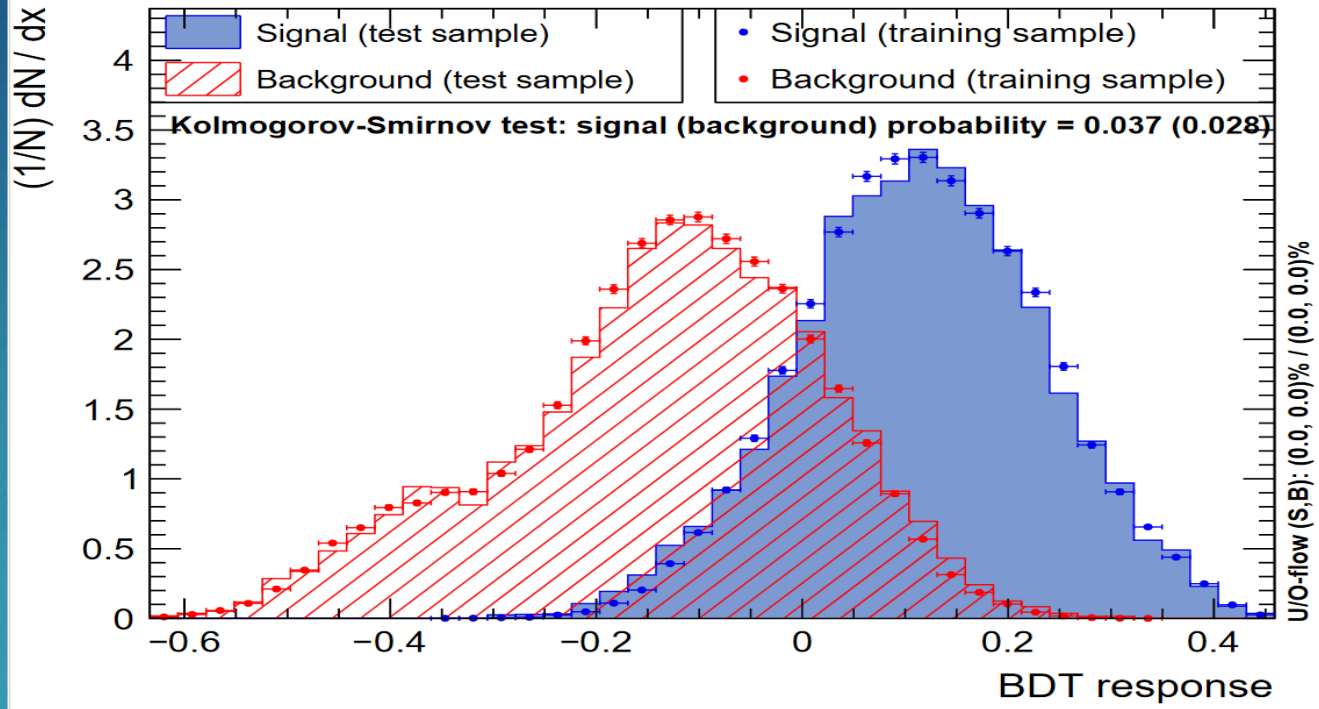
- The energy deposition cuts are susceptible to a high pion contamination.
- Train a multivariate classifier on MC data produced using the clas12-elSpectro event generator.
- The training is done with the ROOT TMVA software package.
- Our positive and negative training samples are then:
  - MC $\mu^+\mu^-$ which pass energy deposition cuts.
  - MC $\pi^+\pi^-$ which pass energy deposition cuts.

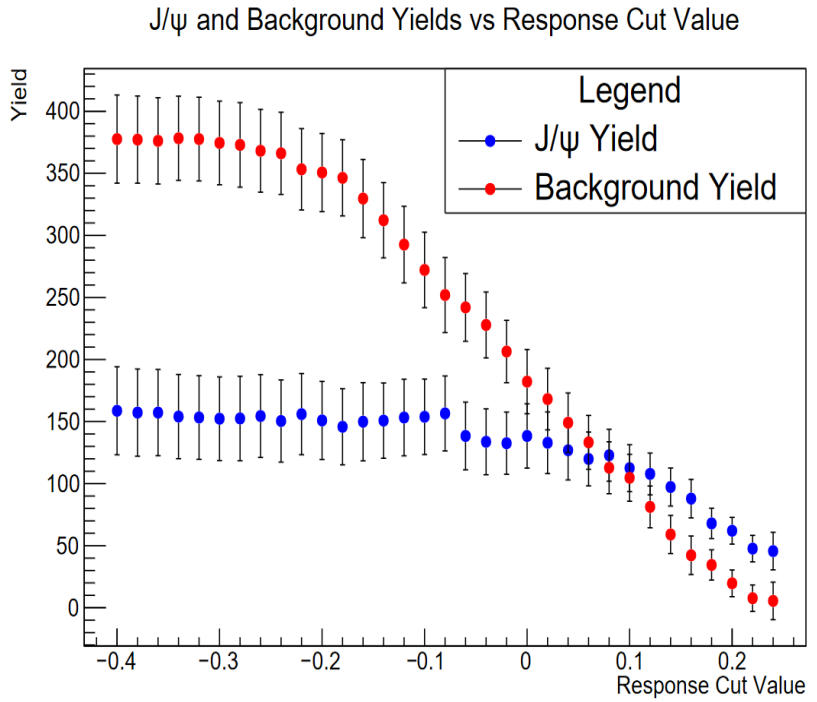




Response

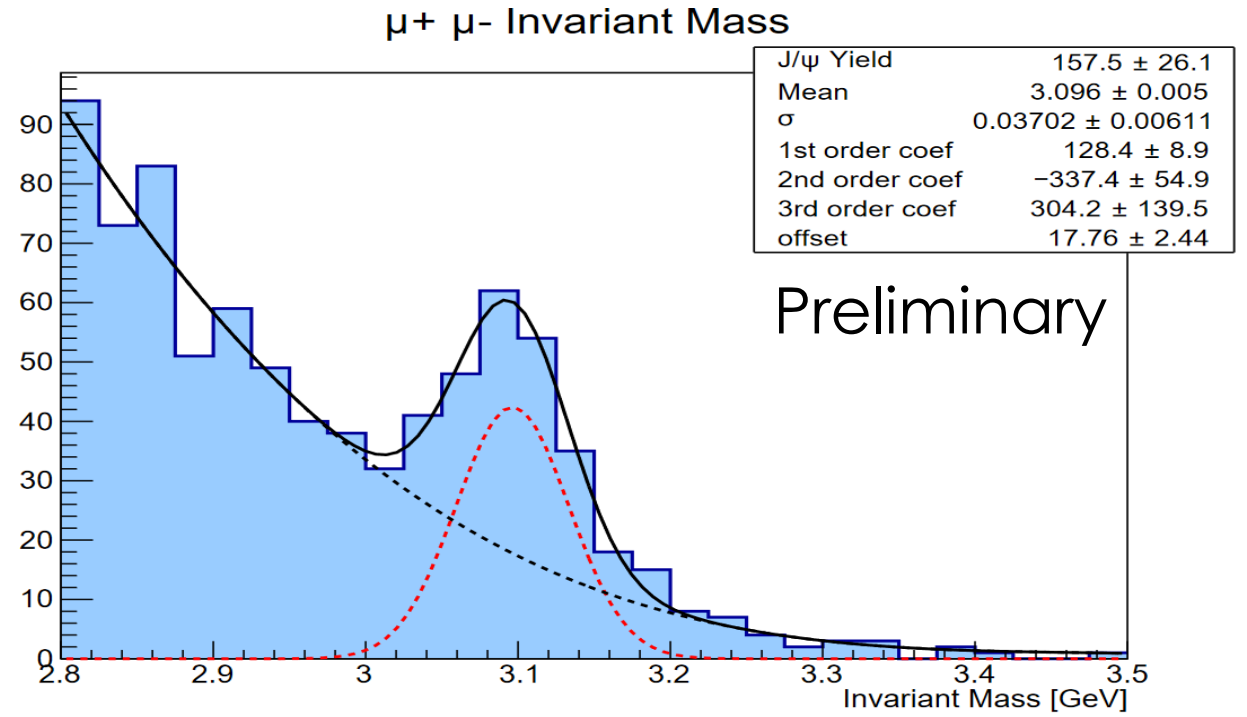
- The classifier output is given as a probability of being a signal event. We call this probability the response.
- The classifier effectively reduces the PID process down to a cut on the response.
- Here we place this cut at -0.12.

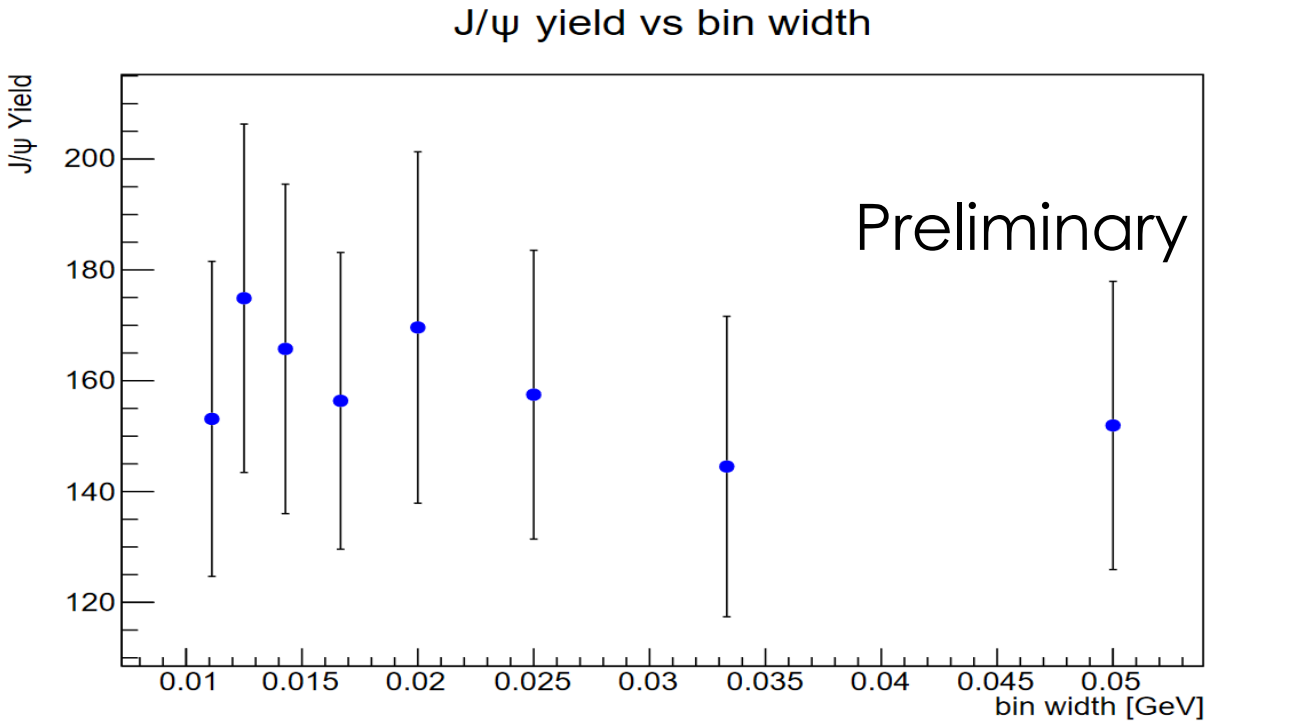




$\mu^+\mu^-$ Invariant Mass in RG-A

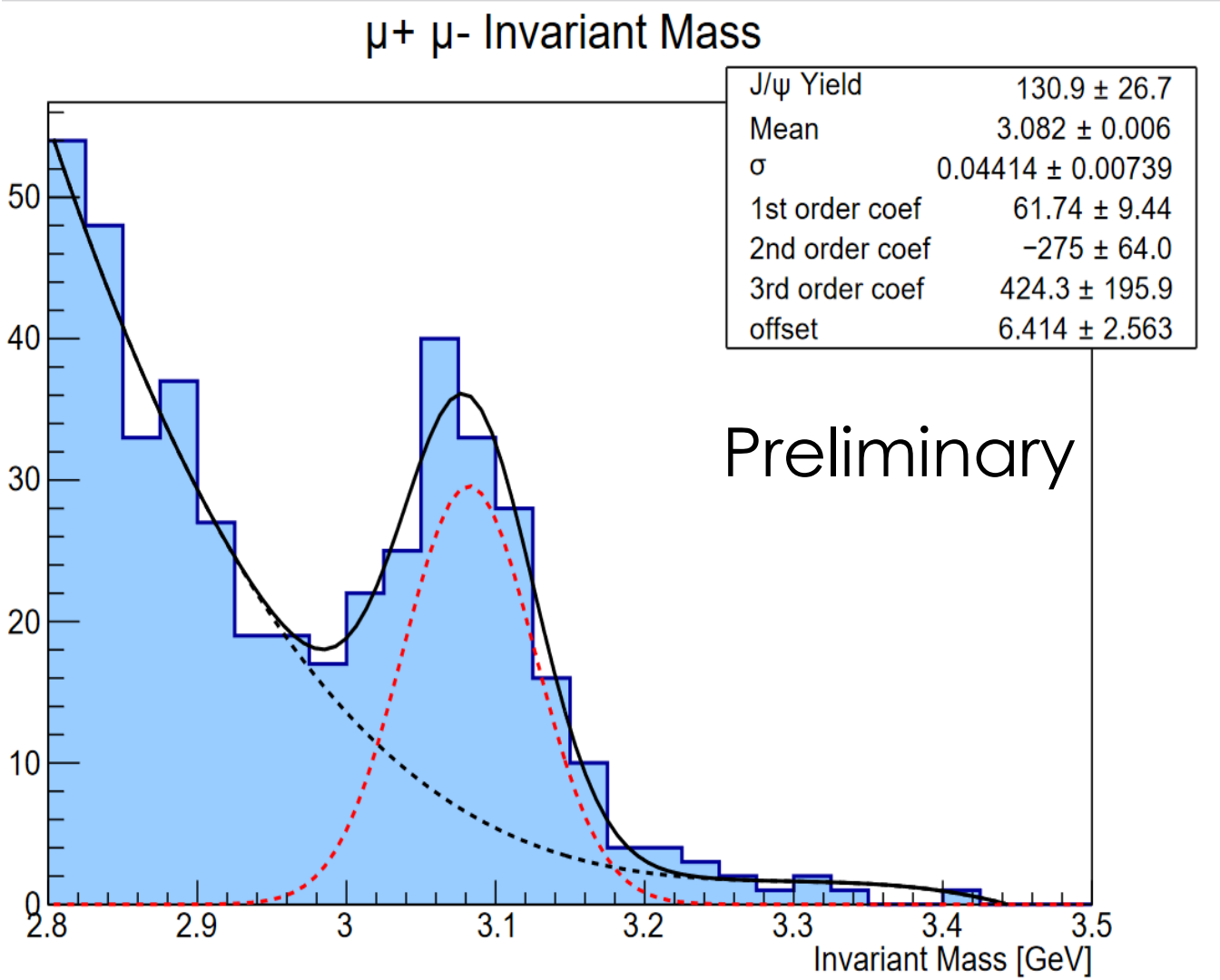
- Produced on RG-A fall2018 dataset, runs 5032 to 5419.
- e^+e^-p has ~166 ± 18 J/ψ in the same dataset.
- No J/ψ signal in the events rejected by our cuts and BDT.





$\mu^+\mu^-$ Invariant Mass in RG-B

- Very very early days of this analysis.
- Produced on full spring2019 dataset.
- Small caveat that the train used here has tighter energy deposition requirements.
- Displacement of $\mu^+\mu^-$ J/ψ mass peak from RG-A to RG-B is 3.096 – 3.082 = 14 MeV. Similar displacement in e^+e^-.



Conclusion and Next Steps

- The analysis for J/ψ photoproduction in the $\mu^+\mu^-$ p final state is well advanced.
- The next step is to calculate the total and differential cross sections.

Backup Slides

PCAL Fiducial Cuts

- Cuts are made on the fiducial region of the PCAL, by removing events close to the edge of the detector in V/W.
- It seems like most of the shower is well contained within the fiducial volume and we don't need these cuts here.