RG-B: J/Ψ in e+ e- p channel

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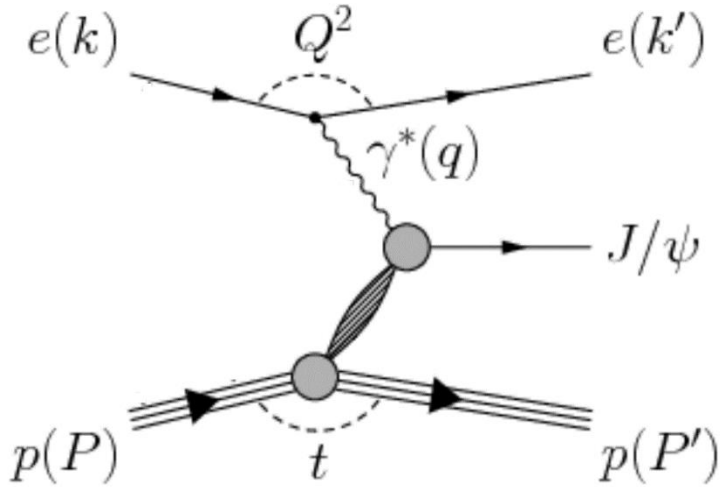
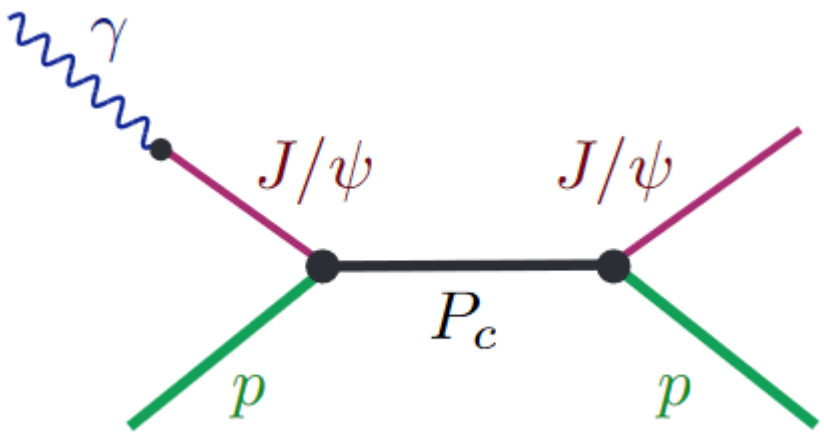
Experiment Overview

$$ed \rightarrow (e')e^+e^-p$$

- The electron beam produced by CEBAF scatters with a deuterium target through the exchange of a quasi-real photon $Q^2 \sim 0$.
- In the $e^+ e^-$ p channel the electron beam interacts with the proton inside the deuteron.
- The proton and e^+e^- pair produced in J/ψ decay are detected in the FD.



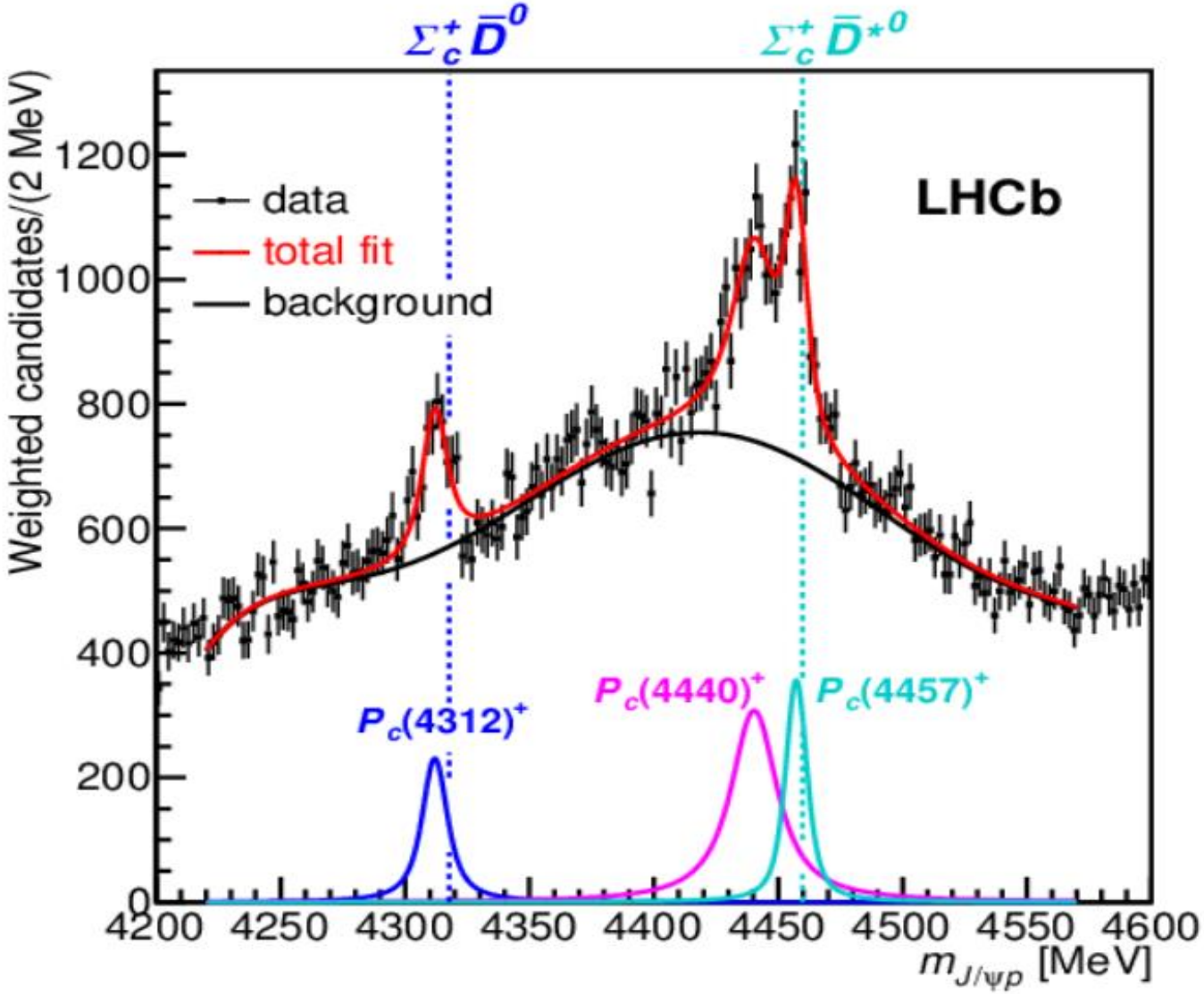
J/ψ quasi-real photoproduction



Feynmann diagram of P_c^+ pentaquark photoproduction.

P_c^+ resonances at the LHCb (2019)

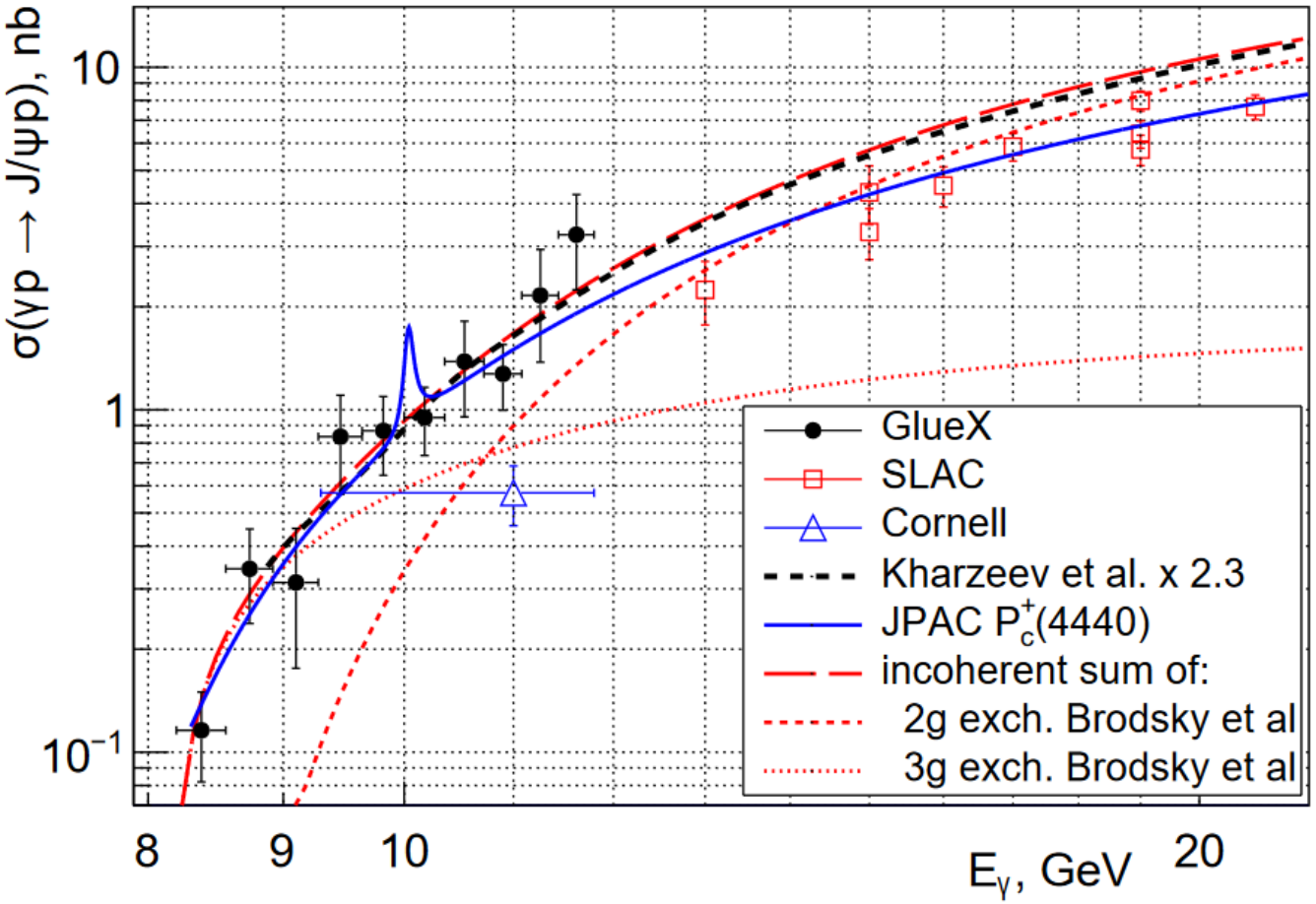
- The e^+e^-n final state further offers the possibility of looking for the isospin partners of the P_c^+ Pentaquarks.



The J/ψ p invariant mass distribution [1].

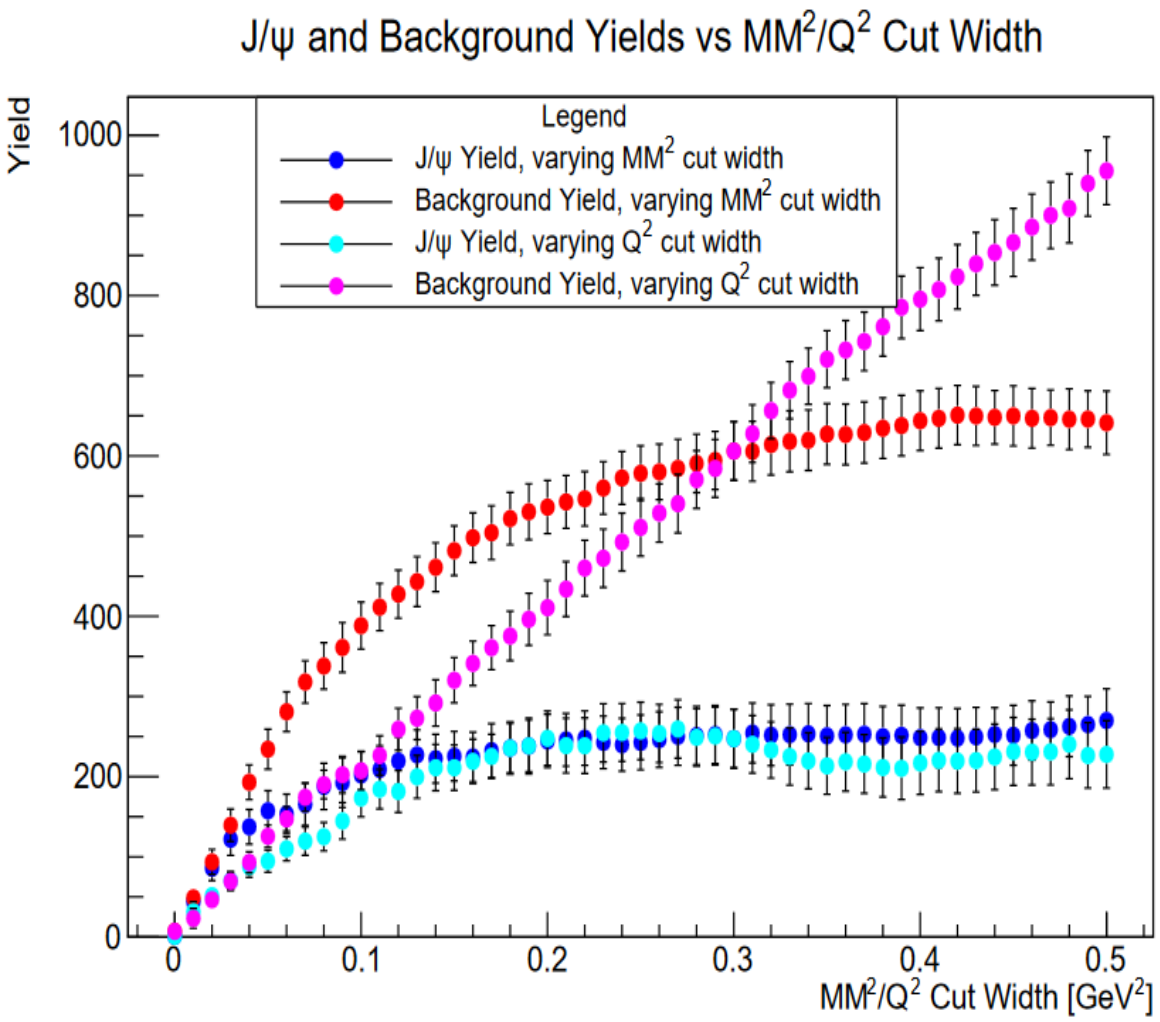
Goals

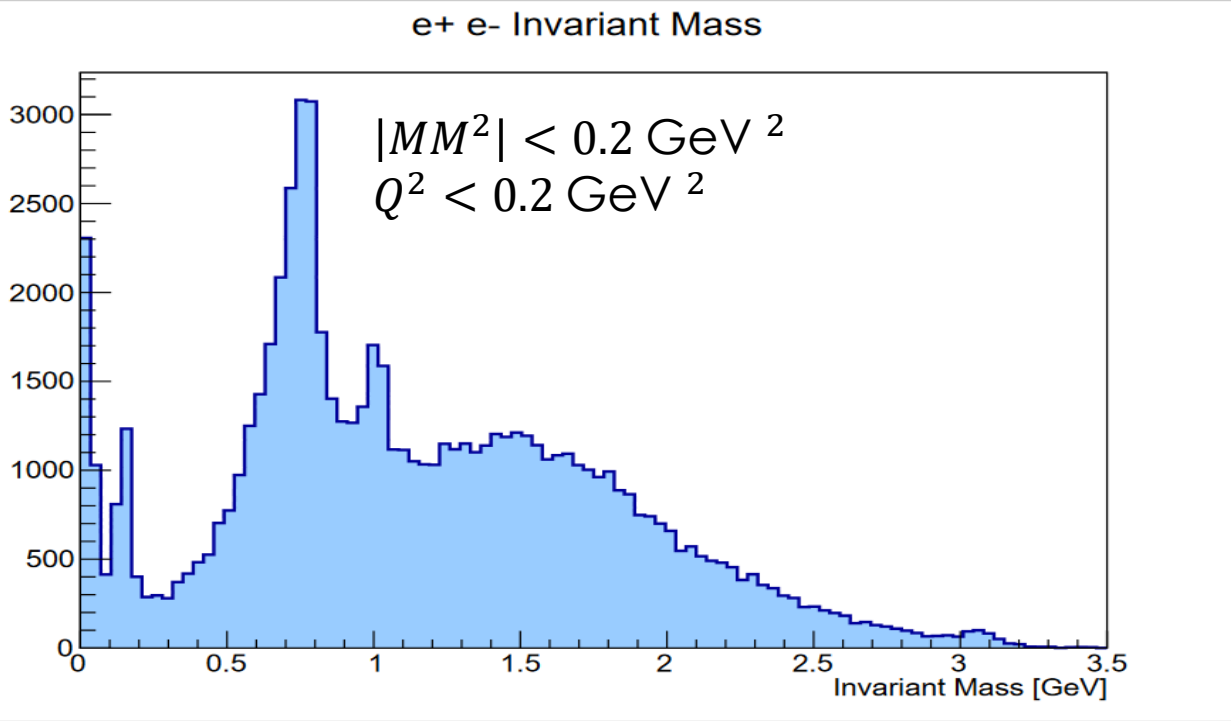
- Verify the LHCb results and look for isospin partners of the P_c^+ Pentaquarks.
- Study the production mechanism of J/ψ near threshold by measuring the total cross section as a function of beam energy.
- Study the distribution of color charge in the nucleon by measuring the t-dependency of the differential cross section of J/ψ photoproduction.

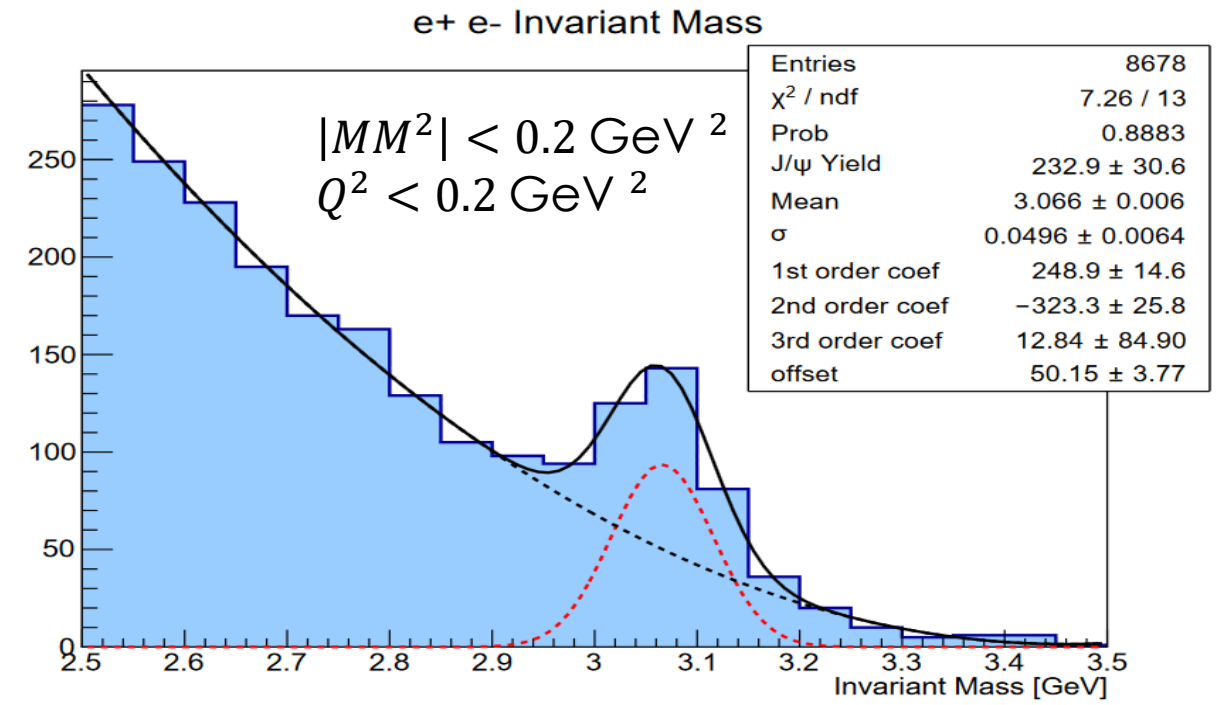


The J/ψ total cross section as a function of beam energy, scaled to GlueX data [2].

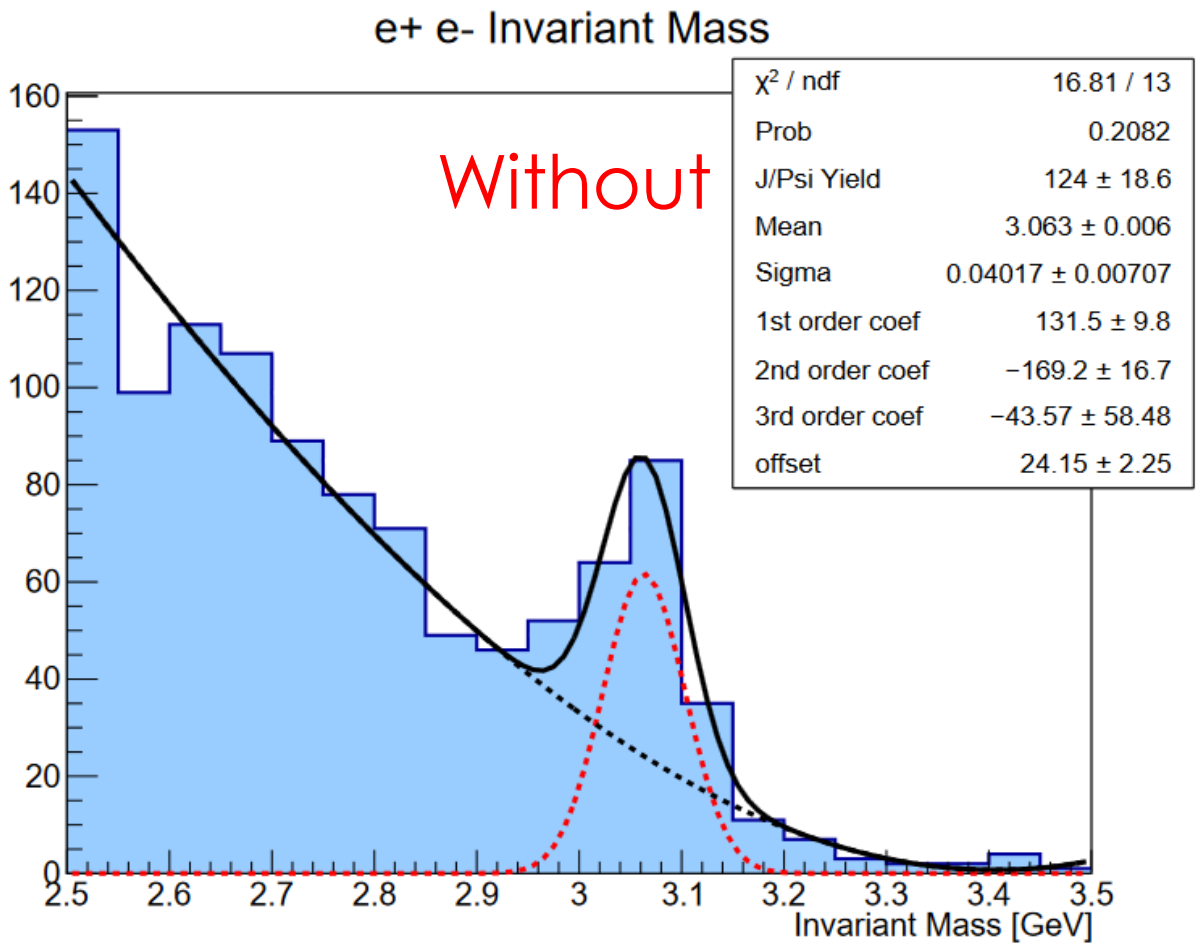
$|MM^2|$ and Q^2 Cuts

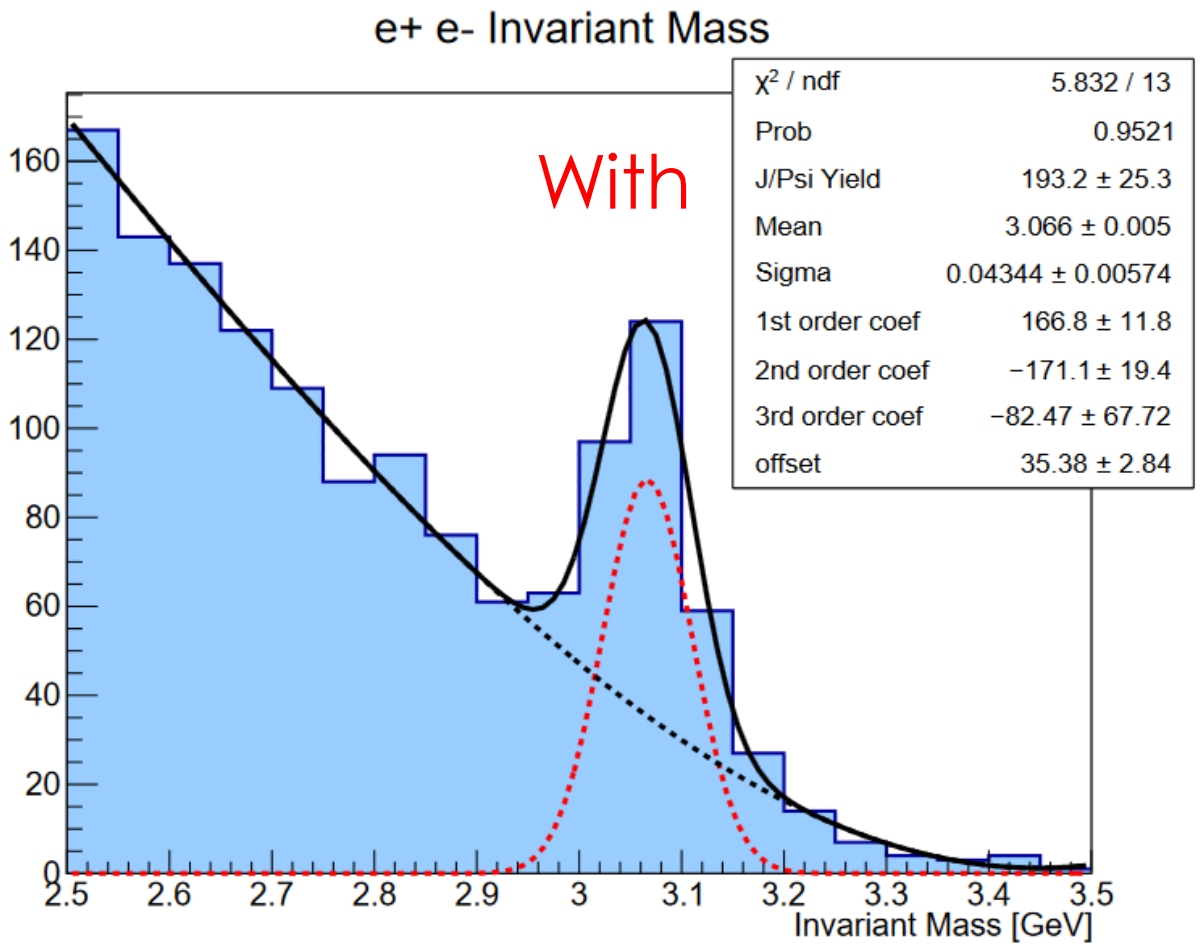






Radiative corrections

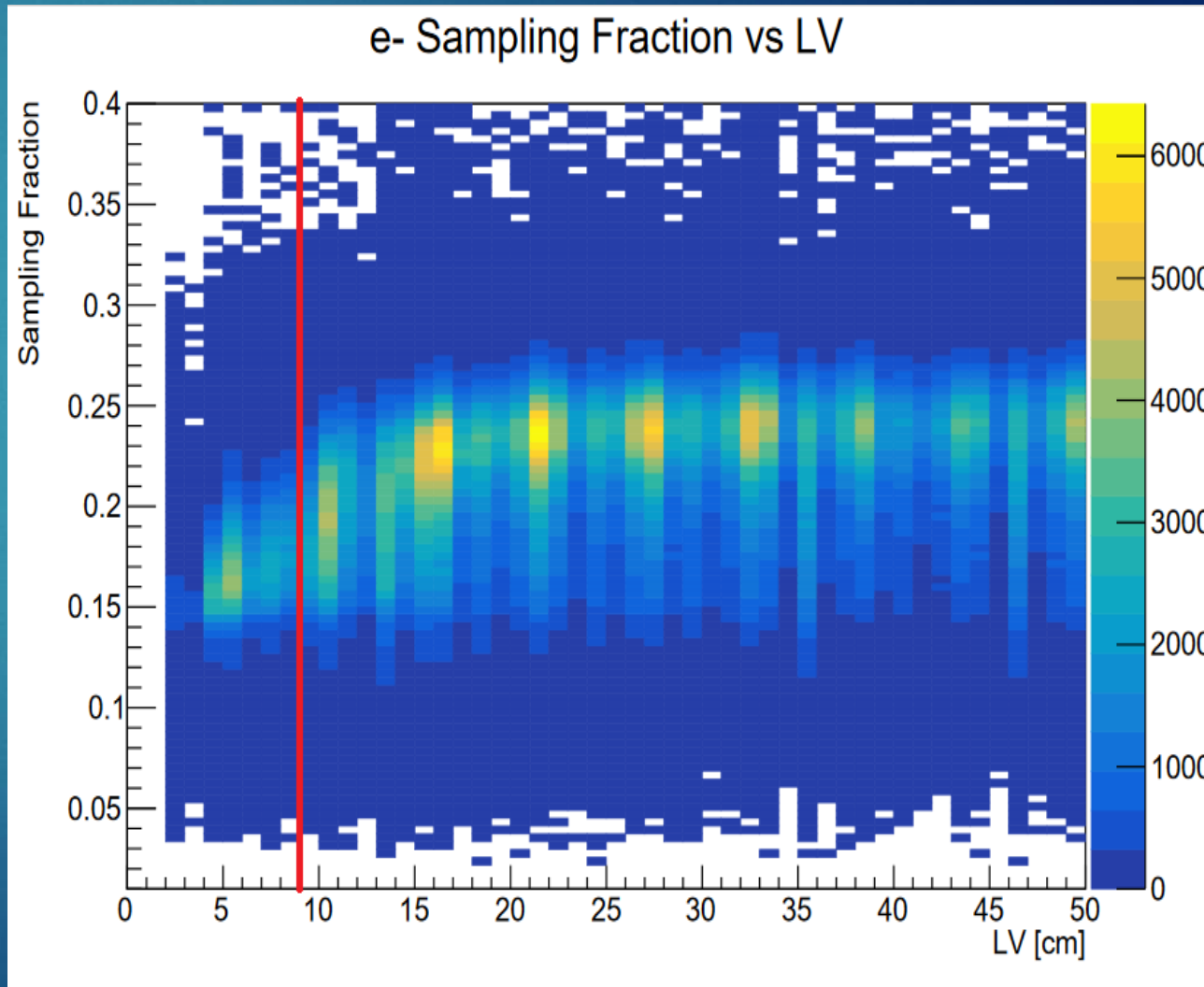




Require $|MM^2| < 0.2$ GeV, $Q^2 < 0.2$ GeV, and some additional PID (cf next few slides).

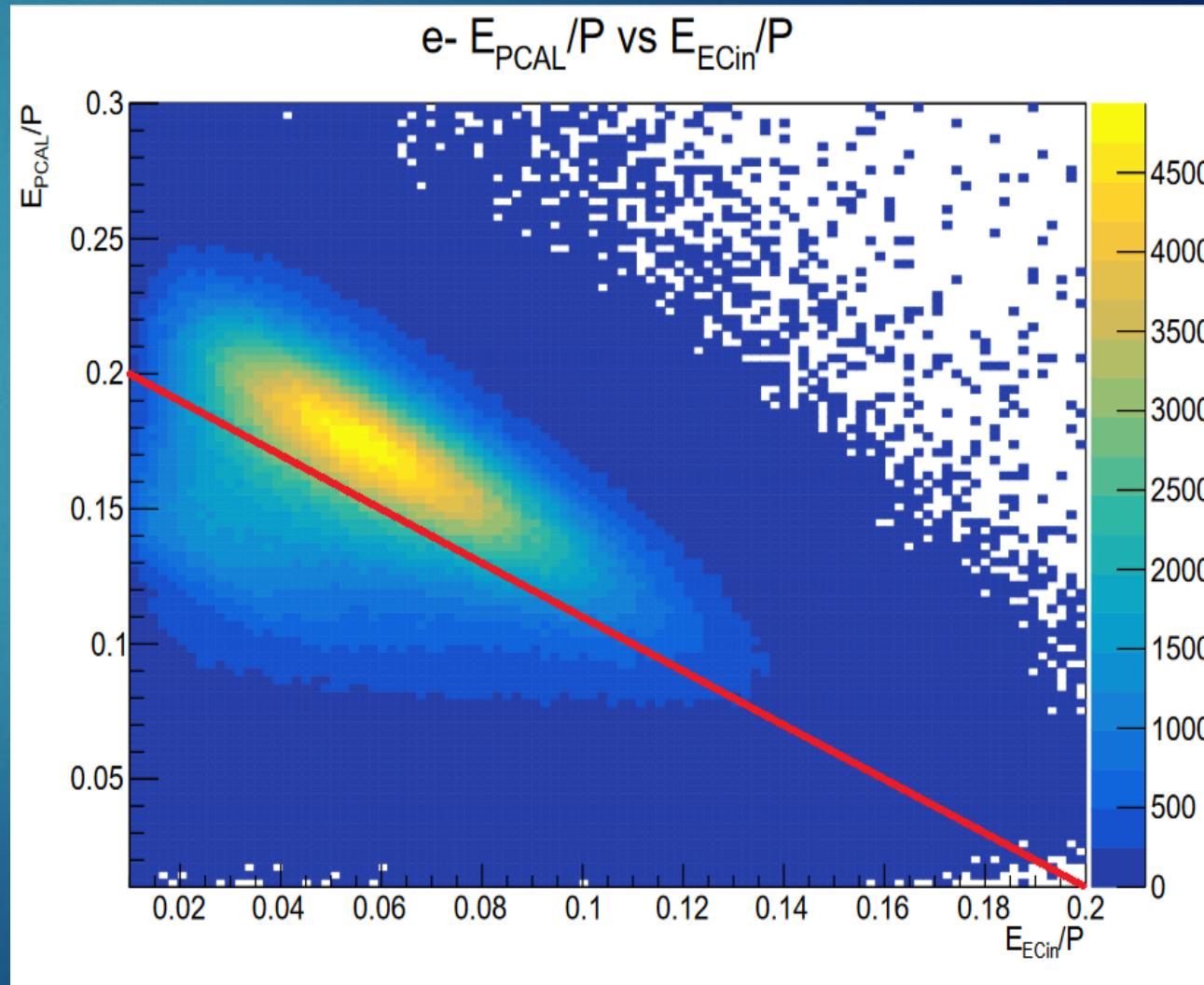
e- PCAL Fiducial Cuts

- The RG-A Analysis note defines fiducial cuts on the PCAL position.
- Here we place this cut at 9cm (2 bars) from the edge of the PCAL in V and W.

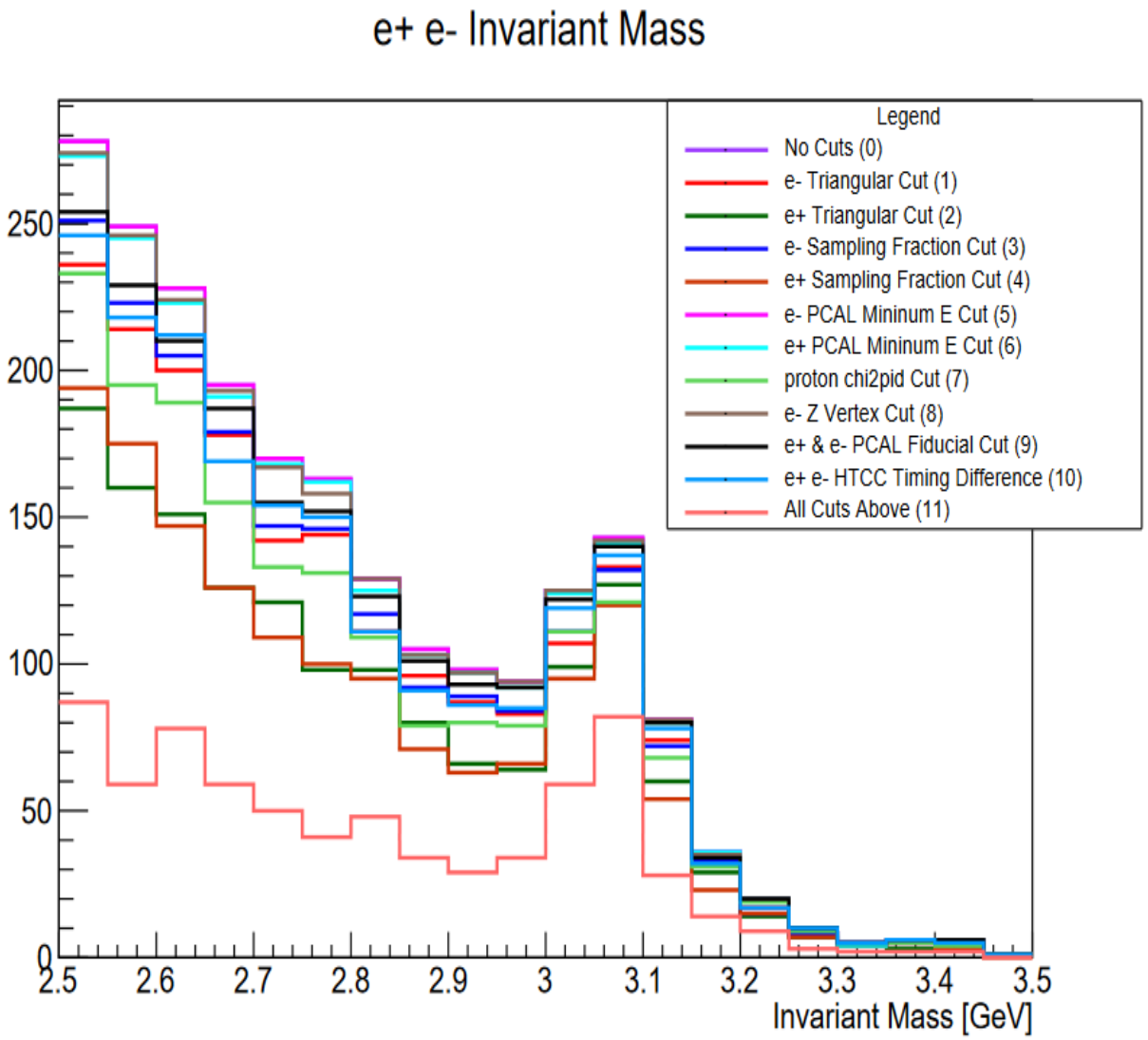


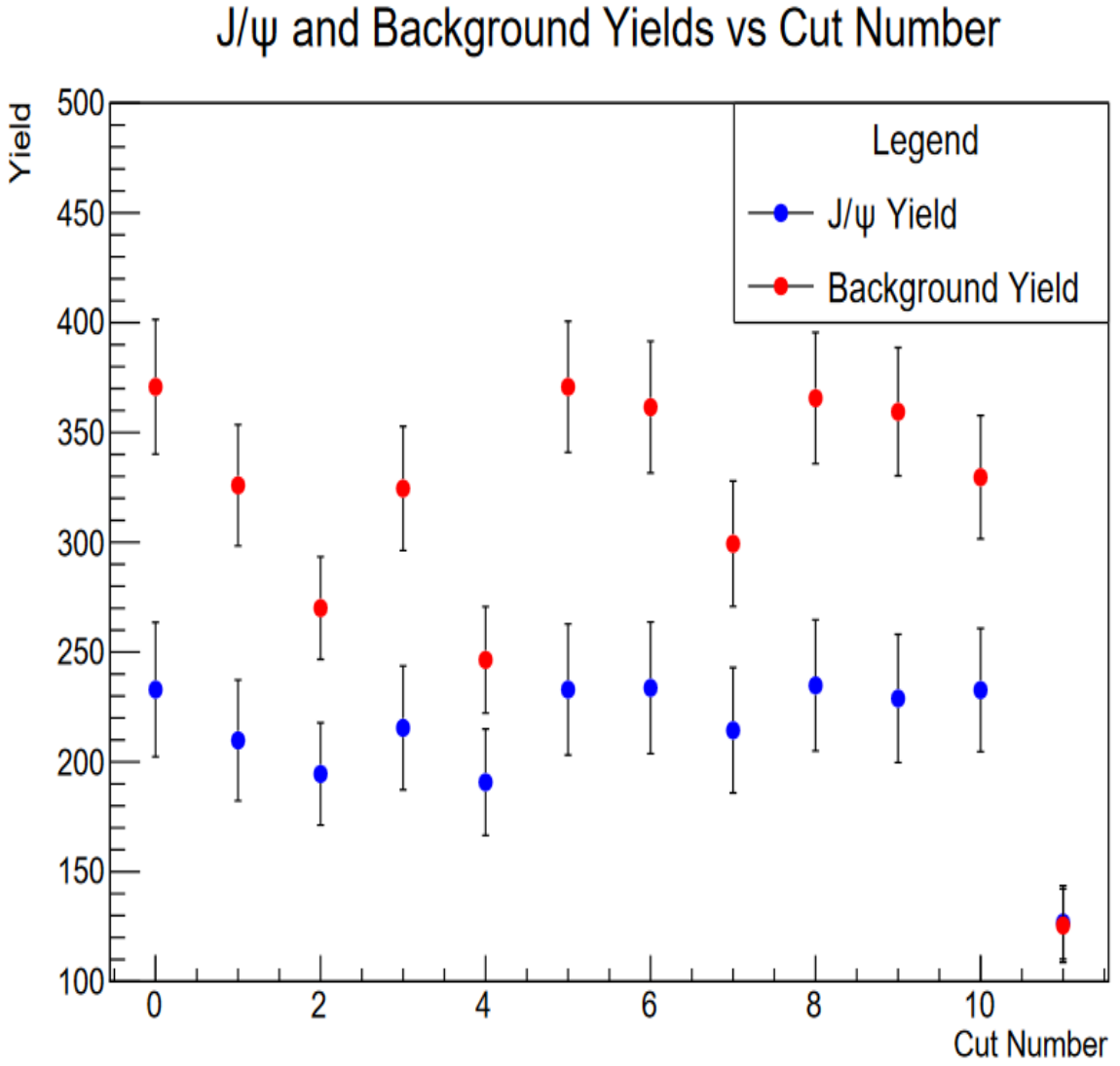
e- ID Refinement

- The RG-A Analysis note defined a list of cuts to improve electron, positron and hadron identification:
  - Triangular cut on individual calorimeters sampling fraction (as shown).
  - 3.5σ cut on the sampling fraction parametrization.
  - 0.07 GeV minimum energy deposition in the PCAL cut.
  - Z-Vertex position cut.
  - 3.5σ chi2PID cut for the proton.
  - 4 ns HTCC timing difference between the electrons and positrons.



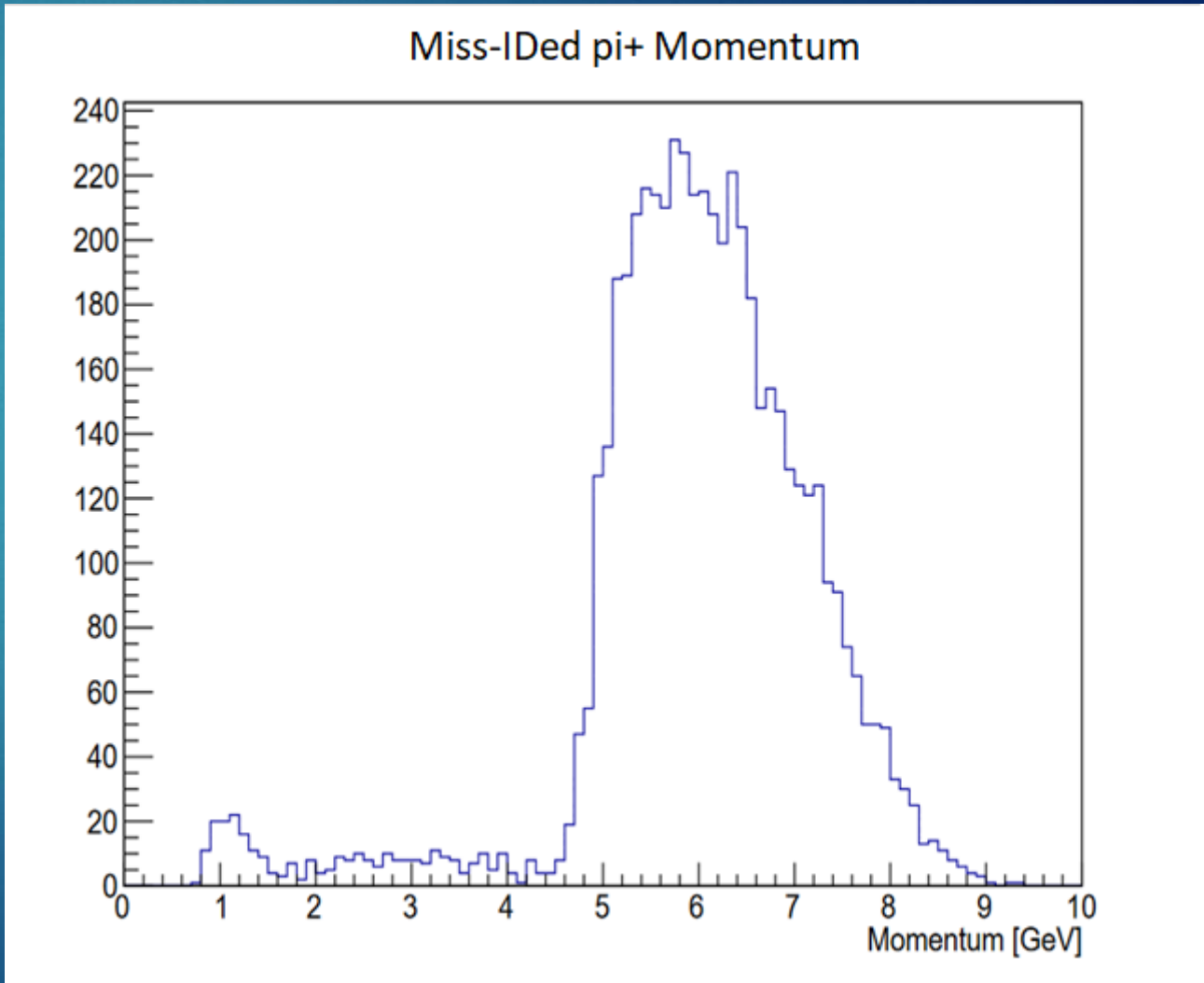
Effect of PID Cuts





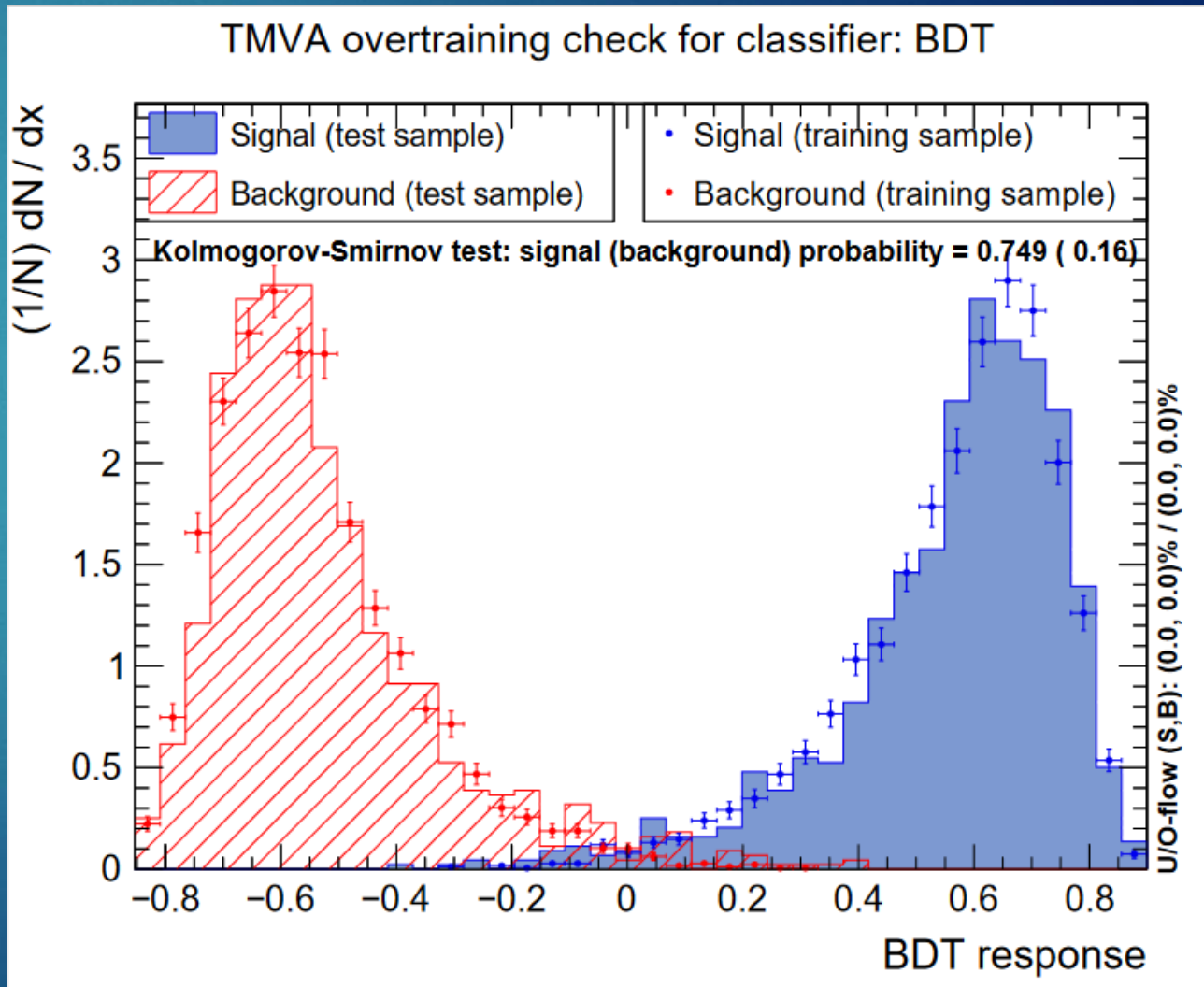
Positron ID Refinement

- From MC we see pions being miss-IDed as positrons above 4.5 GeV, due to the HTCC firing for high momentum pions.
- MC positron as signal training sample.
- MC pion IDed as positron as background training sample.
- Train on PCAL LU/LV/LW and M2U/M2V/M2W, energy deposition in PCAL/ECIN/ECOUT and the number of photoelectrons produced in HTCC.



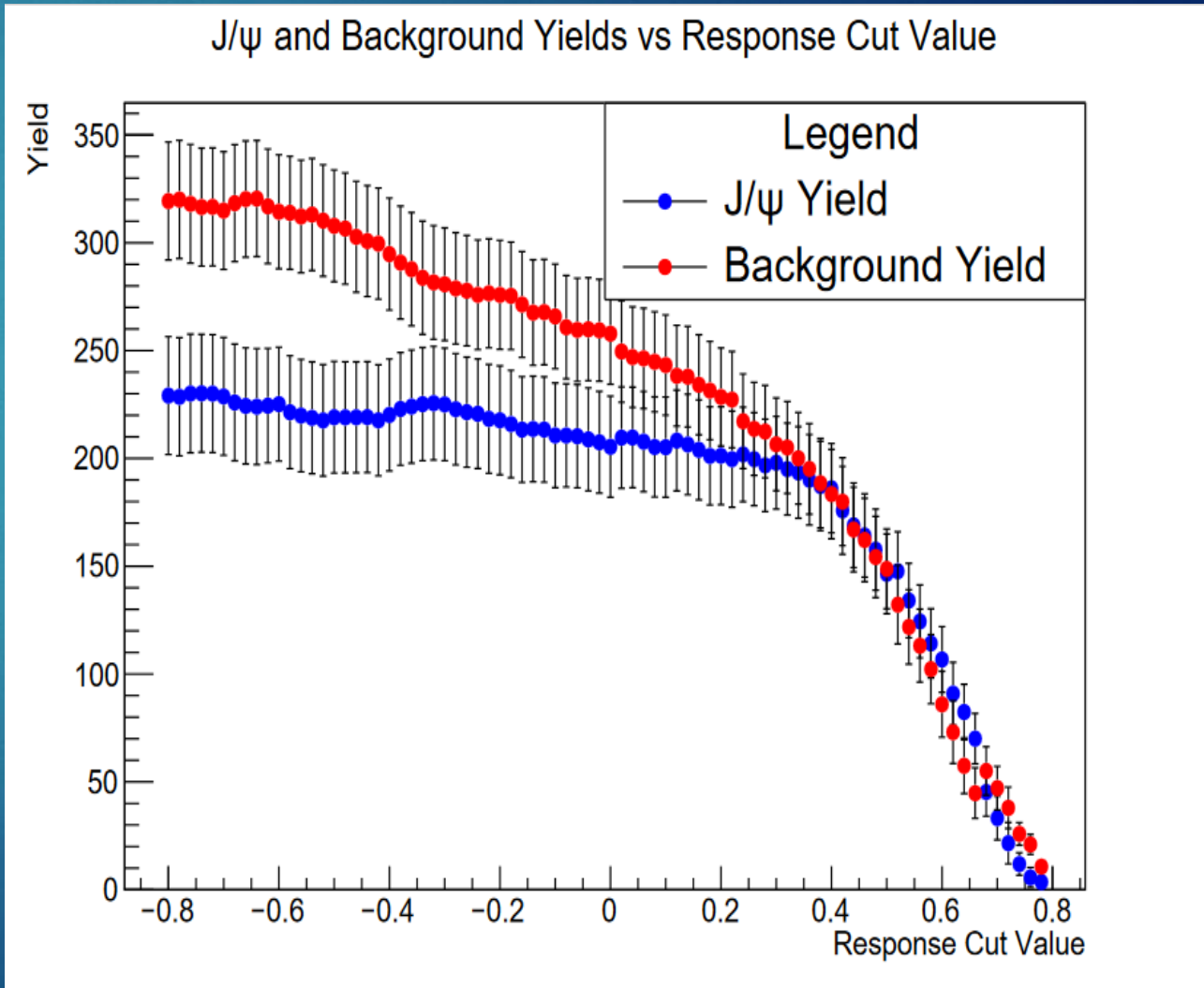
Response

- Trained a Boosted Decision Tree to distinguish between pions and positrons
- The output of the neural network is given as a probability of being a signal event. We call this probability the response.
- A perfect classifier would assign a response of 1 to all signal events and a response of 0 to all background events.
- We choose the threshold above which to call the trigger.



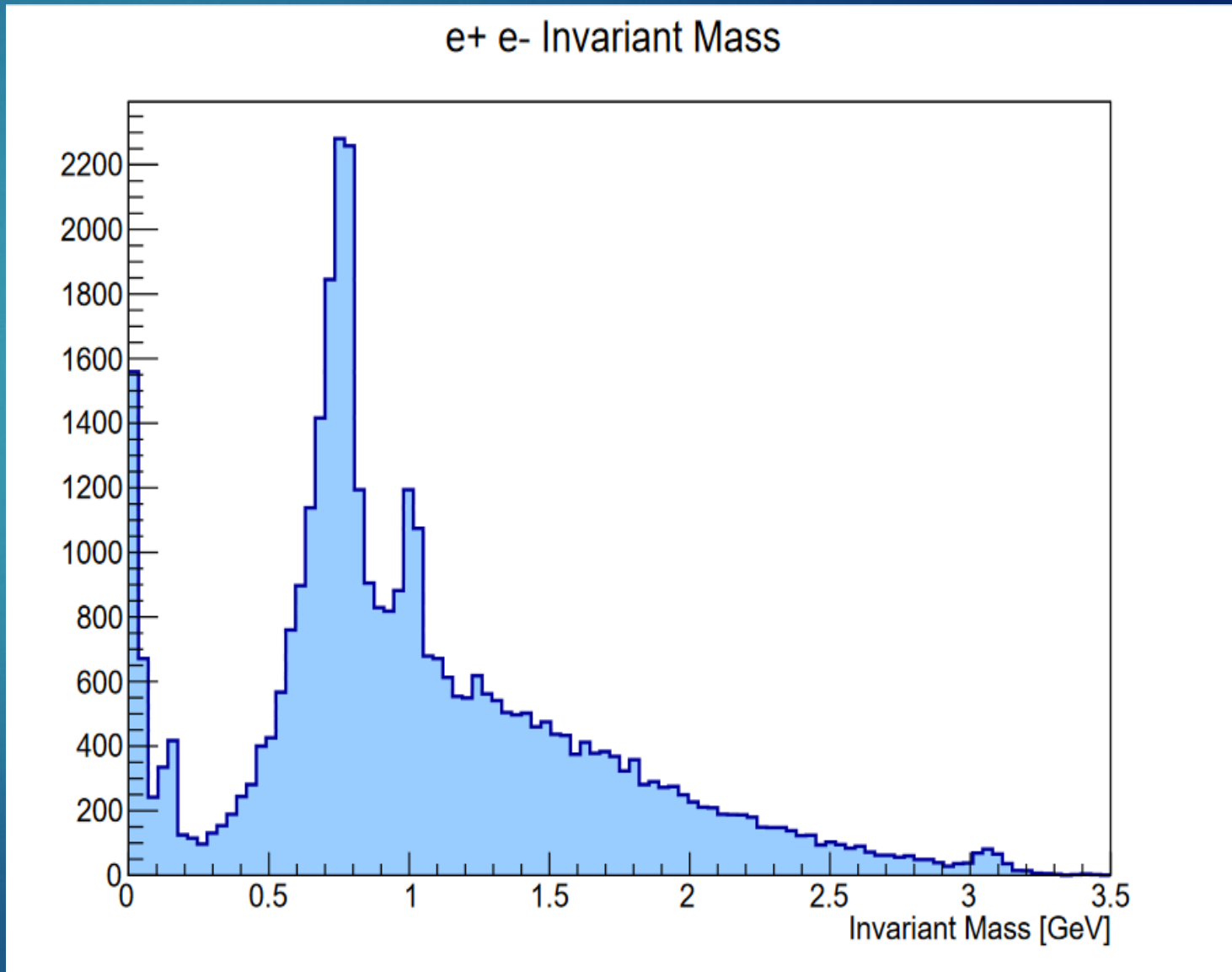
Cutting on the Response

- As we vary the cut on the response, we start to reject signal and background events.
- A tight cut would be placed at high response. Here we chose to place this cut at 0.3.



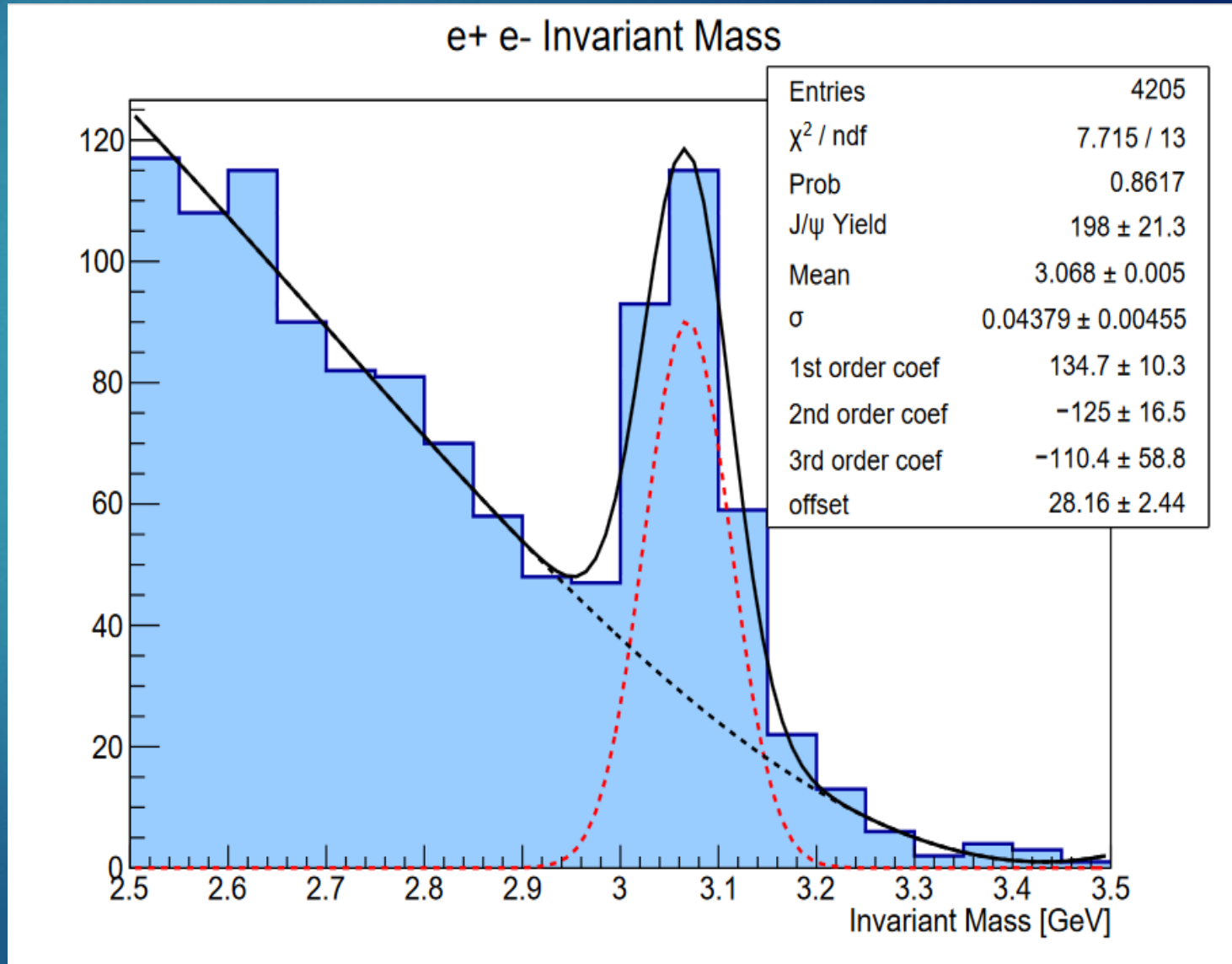
e+ e- Invariant Mass

- $|MM^2| < 0.2$ GeV ^{2}
- $Q^2 < 0.2$GeV ^{2}
- e+ PID response>0.3
- $\Delta T_{HTCC} < 0.4$ns
- Proton and e- EB PID



e+ e- Invariant Mass

- RG-A has ~230 J/ψ events for an accumulated charge of 114 mC (check with Joseph if it's gated or ungated).
- The accumulated charge of the spring2019 RG-B runs was 79.6 mC (gated), 88.6 mC (ungated).



Next Steps

- Calculate the total and differential cross sections for near threshold J/ψ photoproduction ed $\rightarrow$ (e')$e^+e^-\mathrm{p}$. This will provide a healthy cross check to the RG-A measurements.

- Repeat this analysis for the ed $\rightarrow$ (e')$e^+e^-\mathrm{n}$ channel. The main complications will be due to neutron efficiency and reconstruction.

References

[1] R. Aaij et al. (LHCb Collaboration), Observation of a narrow pentaquark state, $P_c(4312)^+$, and of two-peak structure of the $P_c(4450)^+$, *Phys. Rev. Lett.* **122** 22 (2019).

[2] A. Ali et al (GlueX Collaboration), First measurement of near-threshold J/ψ exclusive photoproduction off the proton, *Phys. Rev. Lett.* **123** 072001 (2019).