Observation of $\Lambda K^*(892)$ in electroproduction using RGK Pass-2 Fall-18 Data

CLAS12 Collaboration Meeting

Nov 14, 2024

Veronique Ziegler

Motivation

D.S. Carman, T.-S.H. Lee, M.D. Mestayer, R.A. Schumacher, "Polarized Hyperons Probe Dynamic of Quark Spin", CERN Courier September 2007

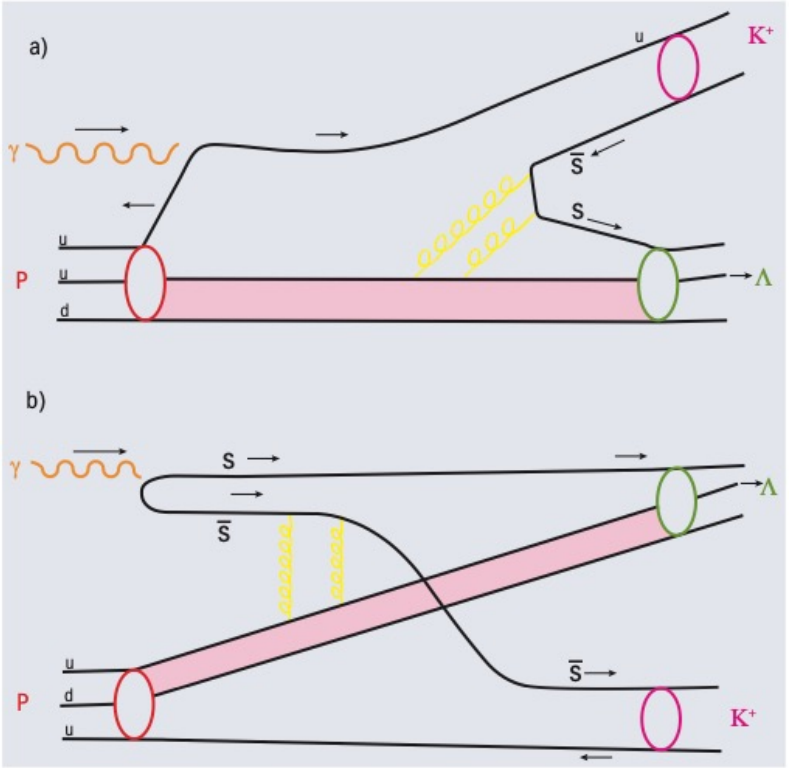


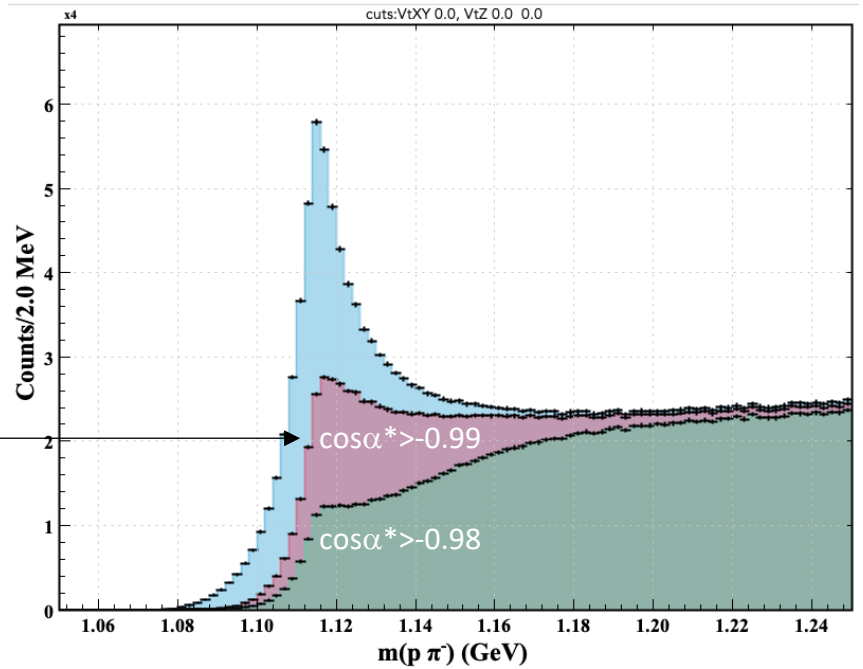
Fig. 2. (a) A model of the reaction where a circularly polarized virtual photon strikes an oppositely polarized up quark inside the proton. The spin of this quark flips and the quark recoils from its neighbours. A strange-antistrange quark pair is created from a $J^{\pi}=0^{-}$ two-gluon exchange (in lowest order) to produce the final state K^{+} and Λ hyperon. (b) A model of the reaction where an $s\bar{s}$ quark pair is produced from a circularly polarized real photon that hadronizes such that the s quark in the Λ retains its full polarization after being "precessed" by a spin–orbit interaction, while the $\bar{s}$ quark ends up in the spinless kaon. In both pictures the shaded band represents a spinless ud di-quark system.

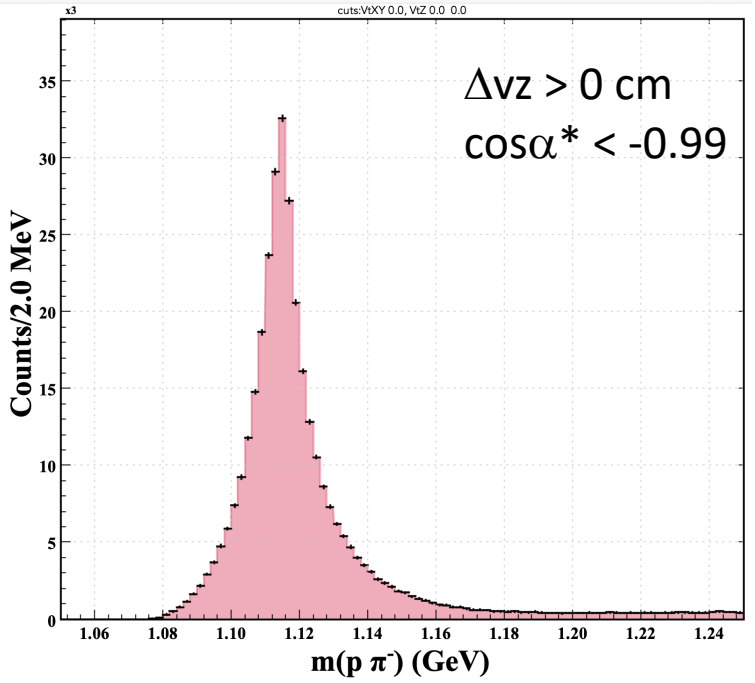
- Studies of beam-recoil spin transfer in electro-produced $K^{+}\Lambda$ final states from unpolarized proton target have shown that the Λ polarization is predominantly in the direction of the spin of the virtual photon.
- Two quark-based models explaining the dynamics with assumption of spectator $J^{PC} = 0^{+}$ di-quark:
  - **The flux tube model** (DS Carman *et al.* 2003 *Phys. Rev. Lett.* **90** 131804): the virtual γ strikes an oppositely polarized u-quark inside the proton. The spin of the u-quark flips (helicity conservation) and recoils from the neighboring quarks causing the gluonic flux tube to stretch. When the flux tube has sufficient energy, an $s\bar{s}$ pair is produced (hadronization). If the $s\bar{s}$ spins are anti-aligned and the spin of the $\bar{s}$ is anti-aligned with the u-quark spin, then the spin of the s-quark is predominantly in the direction of the virtual photon. The Λ spin ~ s-quark spin also in the direction of γ^{*}.
    - …but $s\bar{s}$ pair should be produced with $J^{PC} = 0^{+}$ (aligned 2/3 of the time) according to $^{3}P_{0}$ model
  - **Vector Meson Dominance [photo-production]** (R Schumacher Proc. in EJA): $s\bar{s}$ pair is produced in a $^{3}S_{1}$ configuration. The photon fluctuates into a virtual ϕ meson (with same polarization as photon). The $s\bar{s}$ pair spins aligned with the photon before hadronization. Hence, Λ spin predominantly in the direction of the photon.
- For the **electro-produced $K^{*+}\Lambda$** final state, the spin of the u-quark is the same as for $K^{+}\Lambda$, and if the $s\bar{s}$ pair is produced with anti-aligned spins, the **Λ spin direction should flip**.

Λ Candidate Selection

- Selection of ep→ e ($p\pi^-$) X events using Fall18 (6.5 and 7.5 GeV) Pass-2 RGK data
- Skim these events using detached vertex reconstruction algorithm
    - Creates analysis bank with vertex and momenta of each track and track pair candidate at the reconstructed detached vertex
    - Topology: p & π^- in FD: improved resolution and signal-to-background ratio (study documented in Λ skim CLAS note)
    - PID ($|\chi^2_{PID}|<15$) selection criteria for p and π^-
    - Require the vertex between p and π^- to be reconstructed with doca<5 cm
    - Require Λ vertex to be downstream of the e- vertex
    - Require the cosine of the angle between the proton and pion computed assuming the Λ PDG mass between +/- 1
    - Subsequent vertex displacement (wrt e- vtx) optimization
    - Angle between proton momentum and MM in CM-frame: cosα* < -0.99

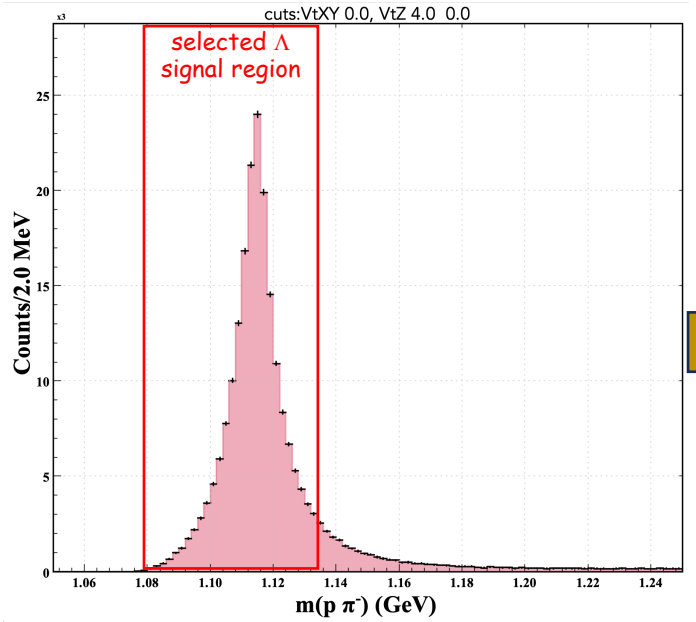
- Small peaking background but higher S/B



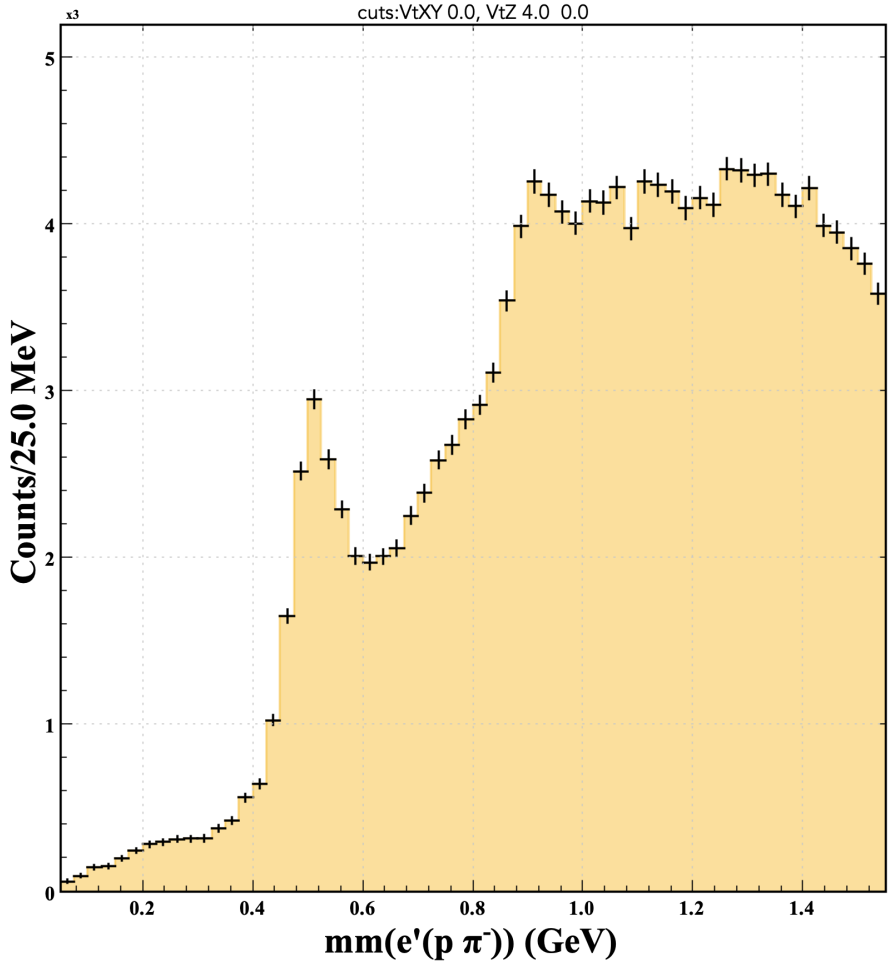


Study of Λ Recoil Candidates

- Missing mass against e^- $p\pi^-$ for selected $\Lambda \rightarrow p\pi^-$ events
- $m(p\pi^-)<1.135$ GeV
- $\Delta(Vz_\Lambda - Vz_e) > 4$ cm
  - Decrease background in mm region above kaon mass



recoil

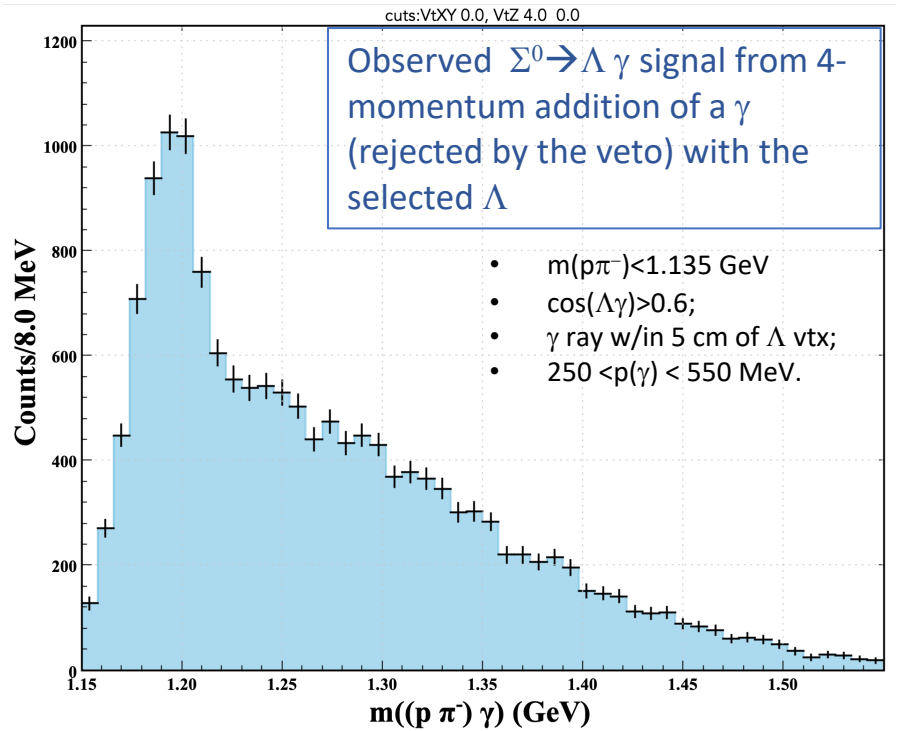


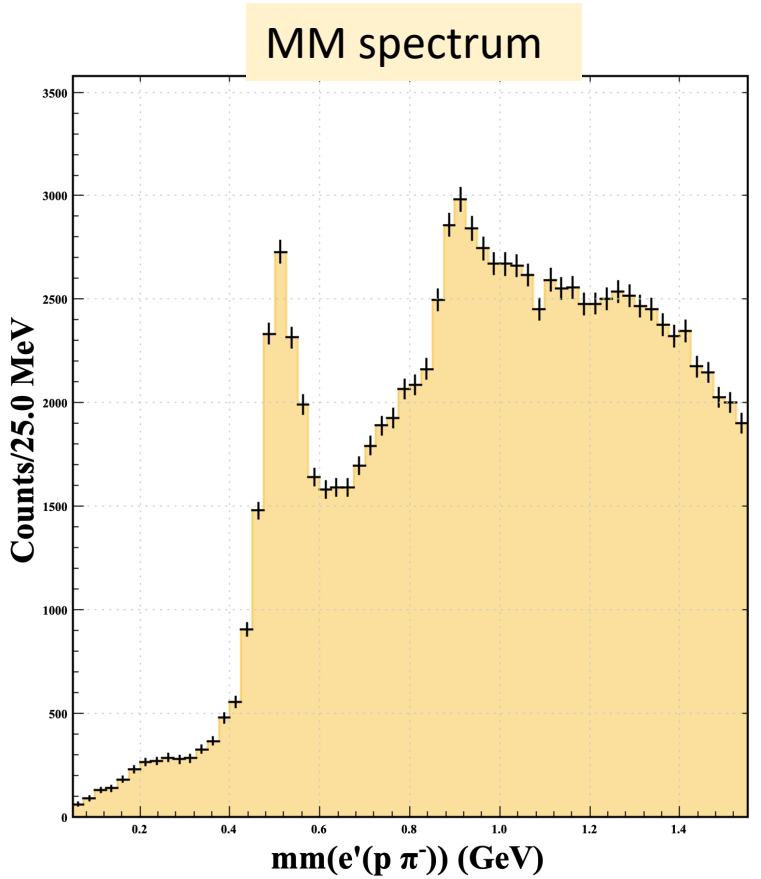
- Clear K+ signal
- Evidence for K*(892)+ on top of high background

Rejection of γ Contamination from e p→e' (Σ→Λ γ) X Events

- Missing mass against e^- $p\pi^-$ for selected $\Lambda \rightarrow p\pi^-$ events
- $m(p\pi^-)<1.135$ GeV
- **$\Sigma \rightarrow \Lambda\gamma$ veto--> rejecting events where there is a photon spanning an angular cone ($\cos\zeta = 0.6$) wrt to the Λ momentum vector**
- **Evidence for $K^*(892)^+$ above high background**

- Photons from the reaction **e p→e' (Σ→Λ γ) X** contribute to background in the MM spectrum
- Applying a cut to reject γ's within an angular cone of the Λ candidate reduces the background under the observed $K^*(892)^+$ spectrum



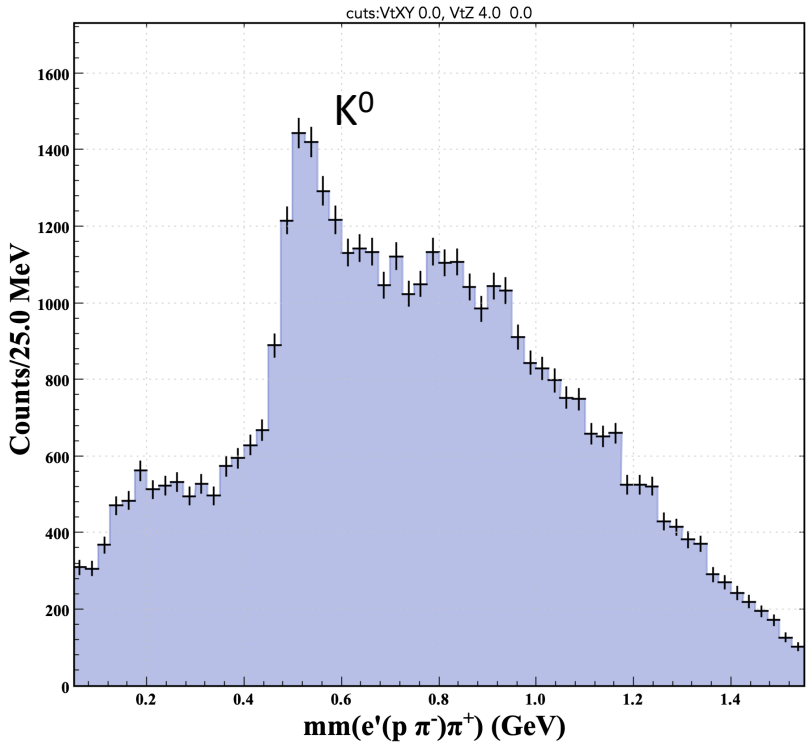


$K^*(892)^+$ Signal Extraction

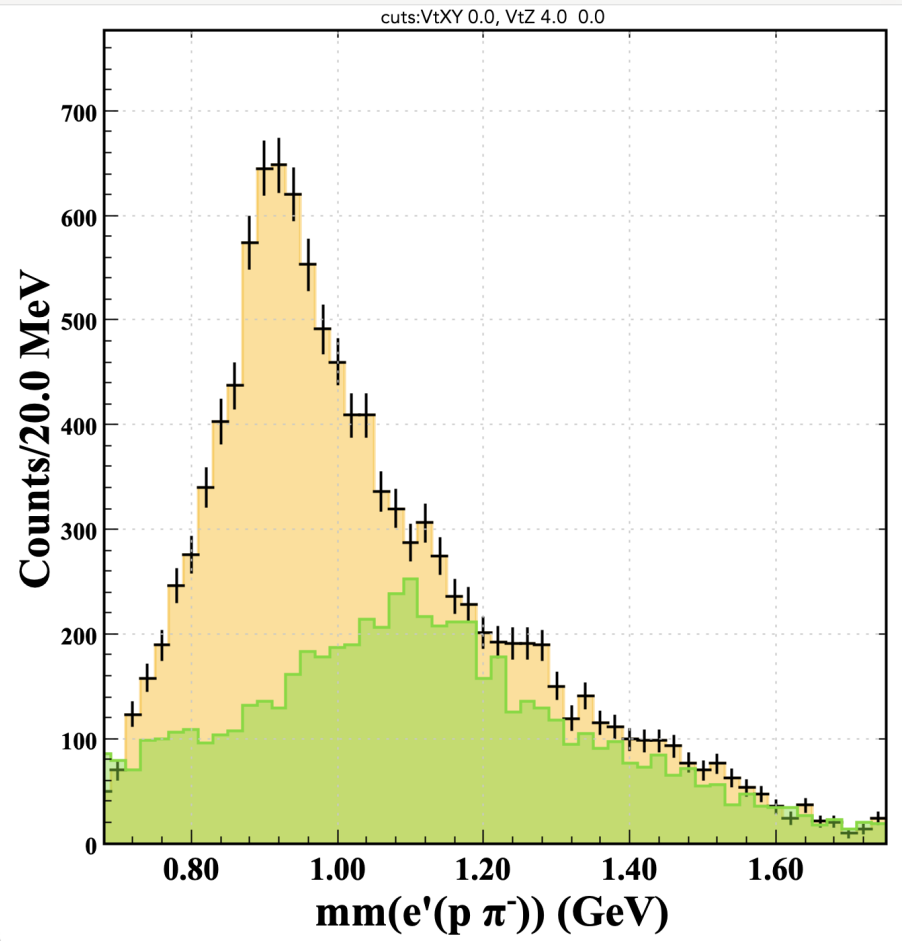
Additional cuts

- **Requiring a π^+ in the event satisfying the condition that [mm(($p\pi^-$) π^+)] be within the K^0 signal region**
- **Clear evidence for $K^*(892)^+$**

- Requiring a π^+ in the event and obtaining the missing mass against e' ($\Lambda \rightarrow p\pi^-$) π^+ yields a clear K^0 peak

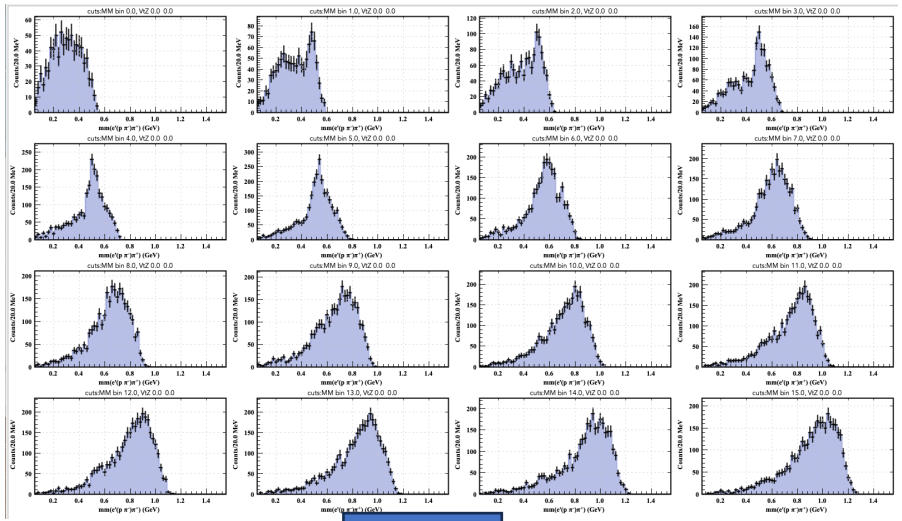


- The missing mass against e' ($\Lambda \rightarrow p\pi^-$) after selecting the K^0 signal region isolates the K* peak
- The K^0 sideband region is shown in green

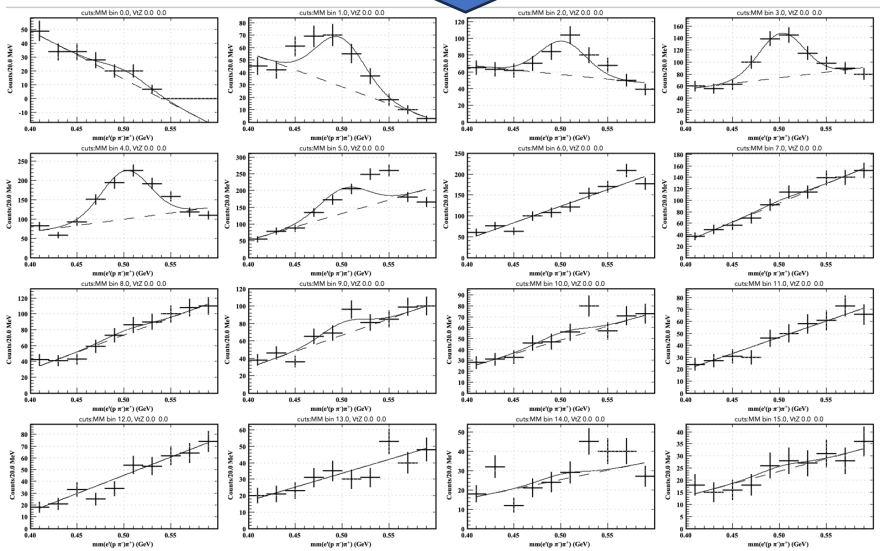


K*(892)$^+$ Background Subtraction

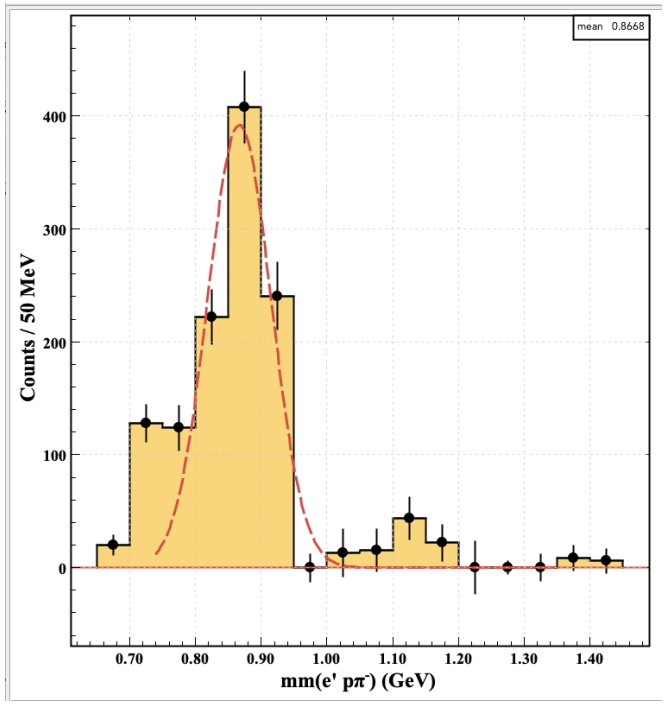
MM(e' ($\Lambda \rightarrow p\pi^-$) π^+) distributions for each mm(e'pπ^-) bin



Zoom with fit



K^0 background-subtracted



- For each bin of the mm(e'pπ^-) spectrum obtain the mm(e'p $\pi^-\pi^+$) distribution and extract the K^0 yield

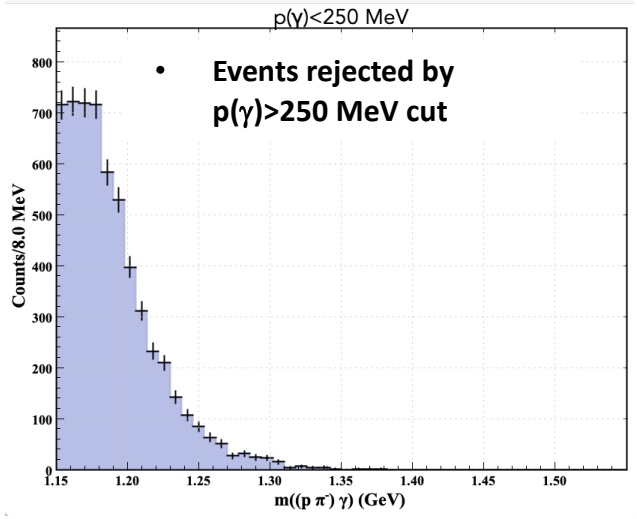
- Very little background (systematics due to fit procedure)
- K*(892)$^+$ signal extraction → measure yield
- Observation of ΛK(892)* channel

Reconstruction of e p→e' (Σ→Λ γ) X Events

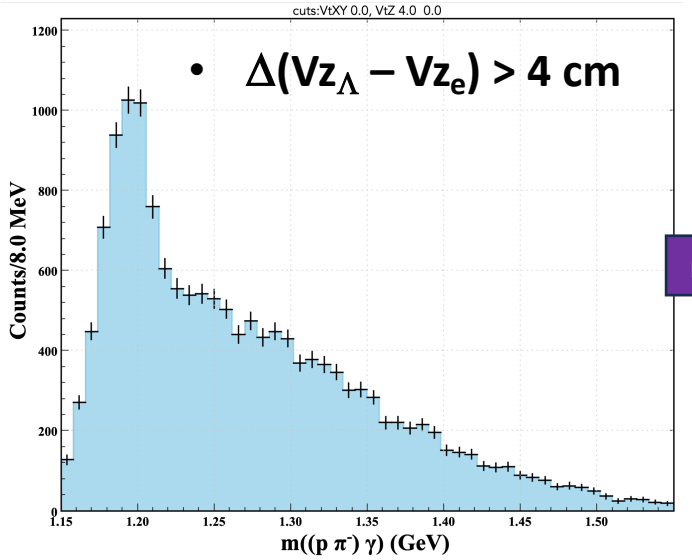
Sigma reconstruction cuts

- doca between the Λ vertex and the γ trajectory line w/in 5 cm;
- cos(Λγ)>0.6;
- m(pπ−)<1.135 GeV
- **p(γ) cuts**

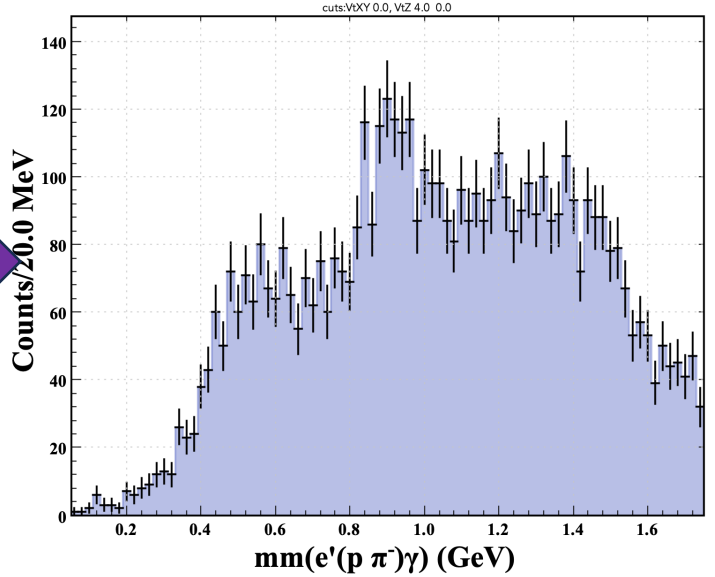
- **Clear evidence for K*(892)⁺ in recoil**

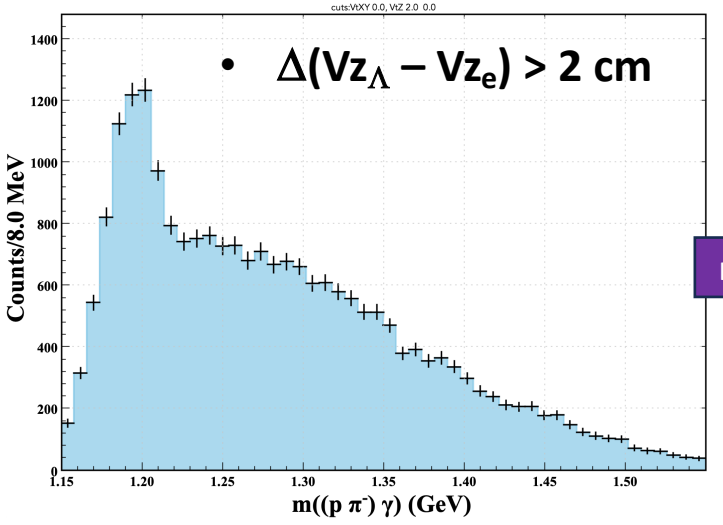


p(γ)>250 MeV

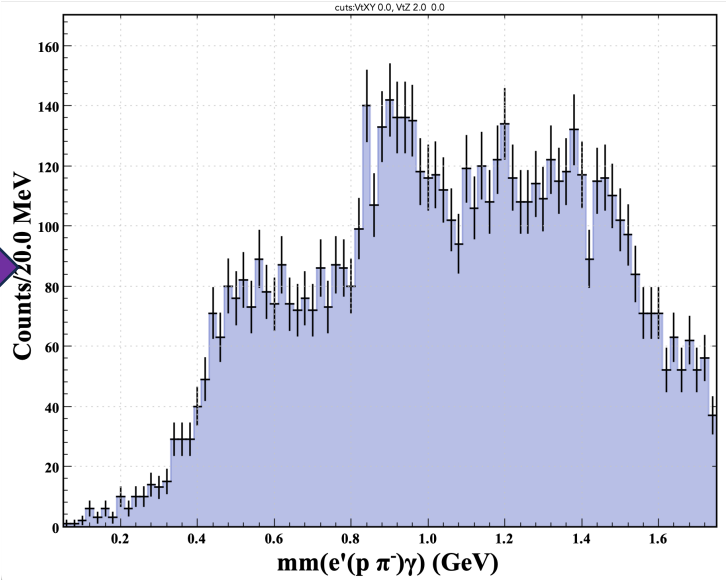


recoil

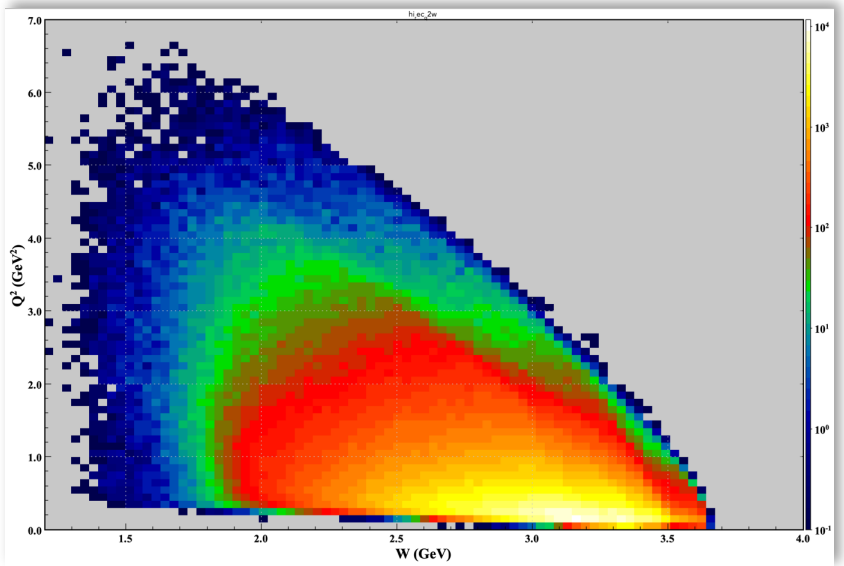




recoil

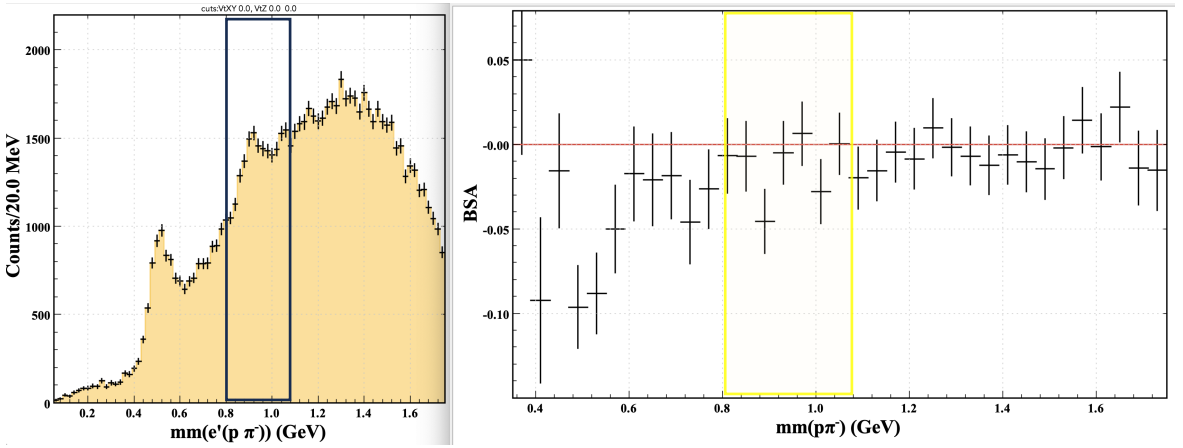


BSA Q^2 Dependence

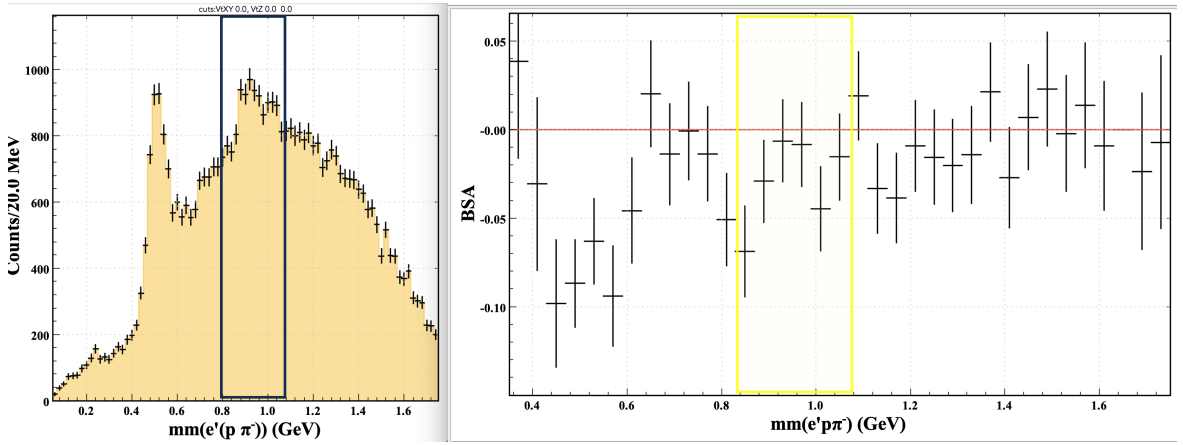


W> 1.5 GeV Events

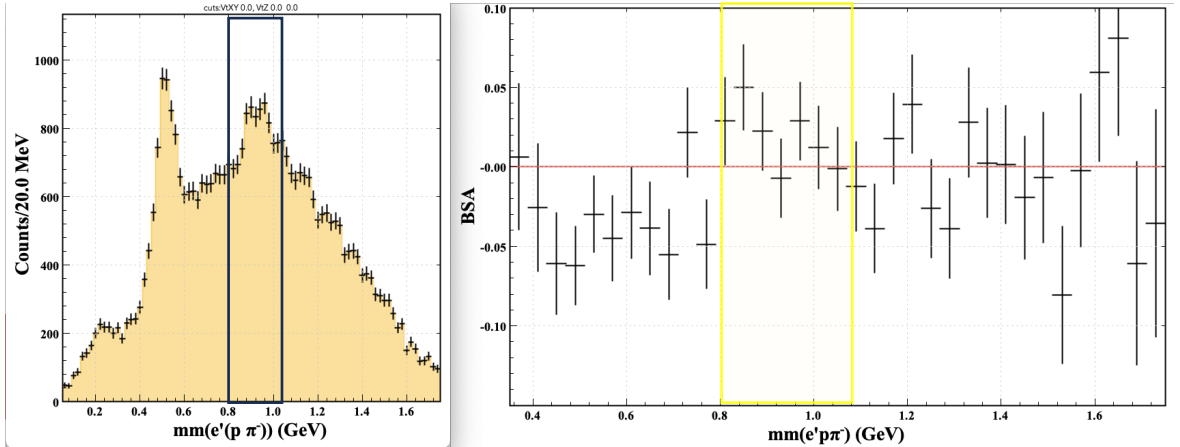
$-Q^2 < 0.5$ GeV^2



$0.5 < -Q^2 < 1.0$ GeV^2



$-Q^2 > 1.0$ GeV^2



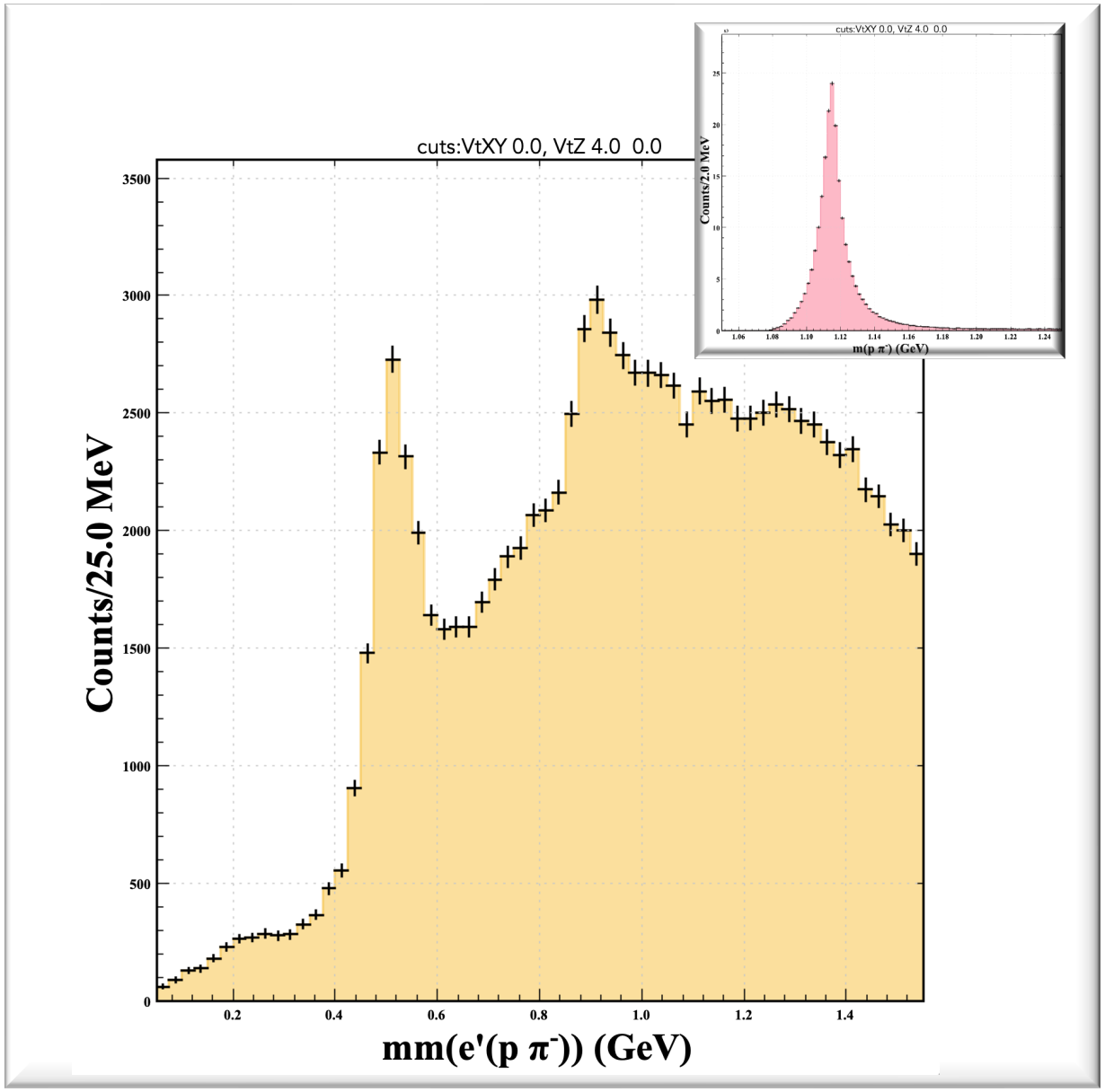
BSA as a function of MM

- Q^2 dependence of BSA
- Enhanced K*(892) signal-to-background ratio at higher Q^2
- Possible BSA sign flip between the K and the K* seen at higher Q^2
- More statistics needed

Outlook

- Evidence for reactions ep → e' $\Lambda(\Sigma^0)$ K^{*+}
  - Study of reaction ep → e' Λ K^{*+} important to shed light into hadronization process involved in Λ production
  - CLAS published results on photoproduction
    - W. Tang et al. (CLAS Collaboration), "Cross Sections for the gamma p --> K^{*+}Lambda and gamma p --> K^{*+}Sigma^0 Reactions Measured at CLAS", Phys. Rev. C 87, 065204 (2013).
    - I. Hleiqawi et al. (CLAS Collaboration), "Cross Sections for the gamma p --> K^{*0}Sigma+ Reaction at Egamma = 1.7 - 3.0 GeV", Phys. Rev. C 75, 042201 (R) (2007).
  - No current results on electroproduction

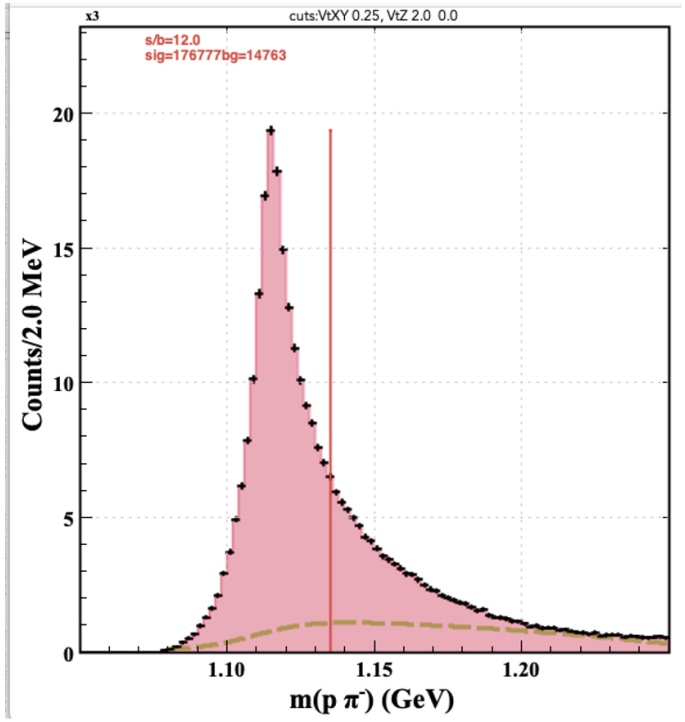
- Possibility of cross section measurement & comparison of induced polarization of the Λ in the reaction ep → e' Λ K^+ to the reaction ep → e' Λ K^{*+}
  - Binning in different kinematics variables requires more statistics → wait for complete 2024 dataset



BACKUP SLIDES

RGA Fall18

- m($p\pi^-$) spectrum



Missing mass against $e^-p\pi^-$ for selected $\Lambda \rightarrow p\pi^-$ events for m($p\pi^-$)<1.135 GeV