A Λ Skim for CLAS12

CLAS12 Collaboration Meeting

Nov 14, 2024

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Motivation

- Events containing a Λ particle produced in CLAS12 with rates sufficient to yield interesting results for strangeness electro- and photo-production.

- Exclusive reconstruction of Λ candidates allows to search for several reactions involving a baryon with strangeness S = 1, 2, 3 with improved resolution over the missing against kaon(s).

- Exclusive reconstruction of the Λ allows for precision beam spin asymmetry and polarization measurements that can be compared with previous inclusive measurements where only the proton was measured.

- Exclusive $\Lambda \rightarrow p\pi^-$ reconstruction allows use of detached vertex of the Λ wrt a reference vertex (i.e. e^-) which is a powerful tool to reject the background under the Λ candidate peak.

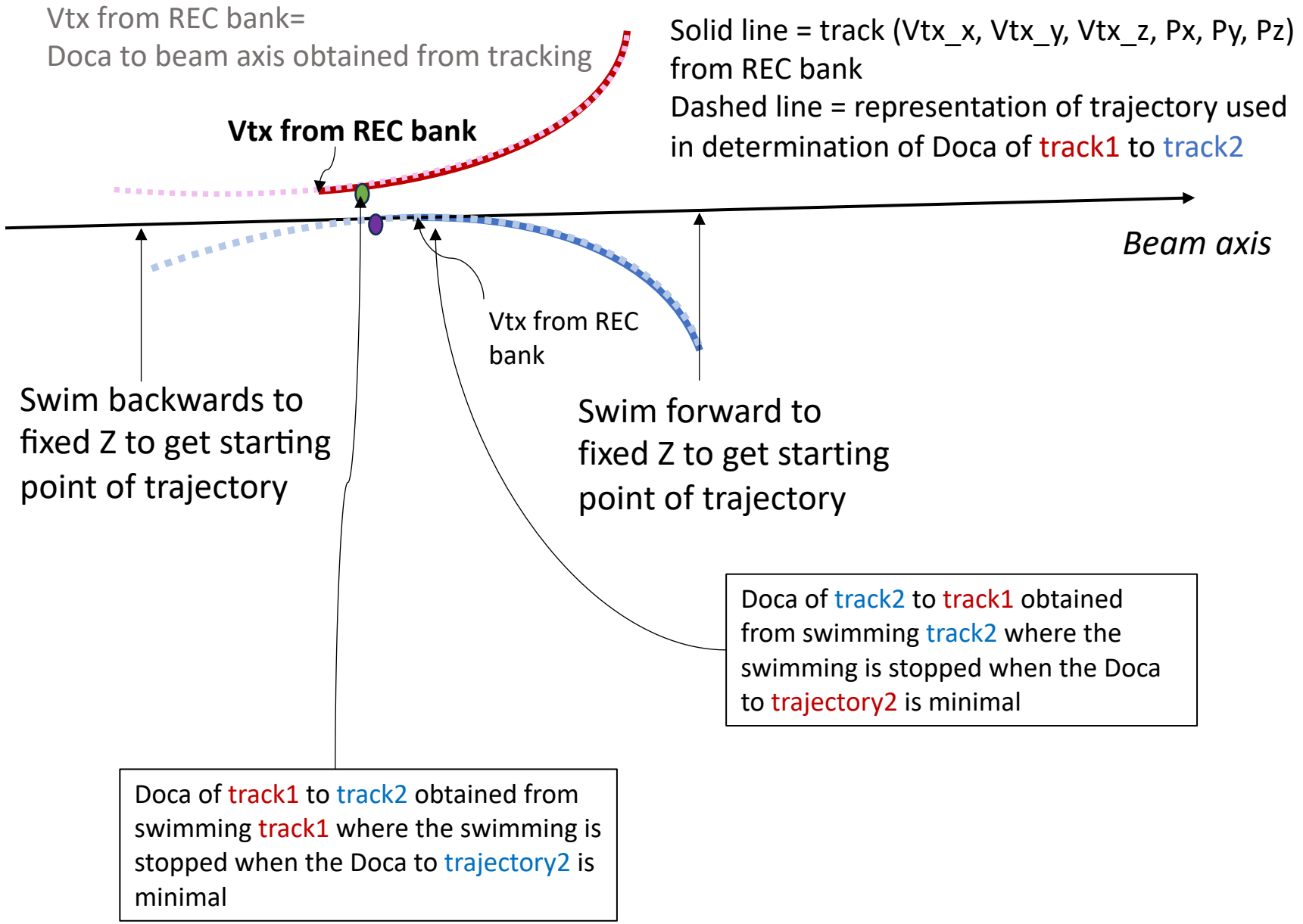
- $\Lambda \rightarrow p\pi^-$ selection criteria studied using RGK runs 19334, 19335, 19336, 19337, 19339, 19340, 19341, 19343, 19348, and 19349 collected during the Spring of 2024. Validation done on RGK 6.5, 7.5 GeV data sets and RGA Fall-18, Spring-19 datasets.

Detached Vertex Finder Algorithm

1. For each track
   1. Swim backwards to fixed Z to get starting point of trajectory
   2. Swim forward to fixed Z to get starting point of trajectory

2. Compute Doca of track2(1) to track1(2) obtained from swimming track2(1) where the swimming is stopped when the Doca to trajectory2(1) is minimal

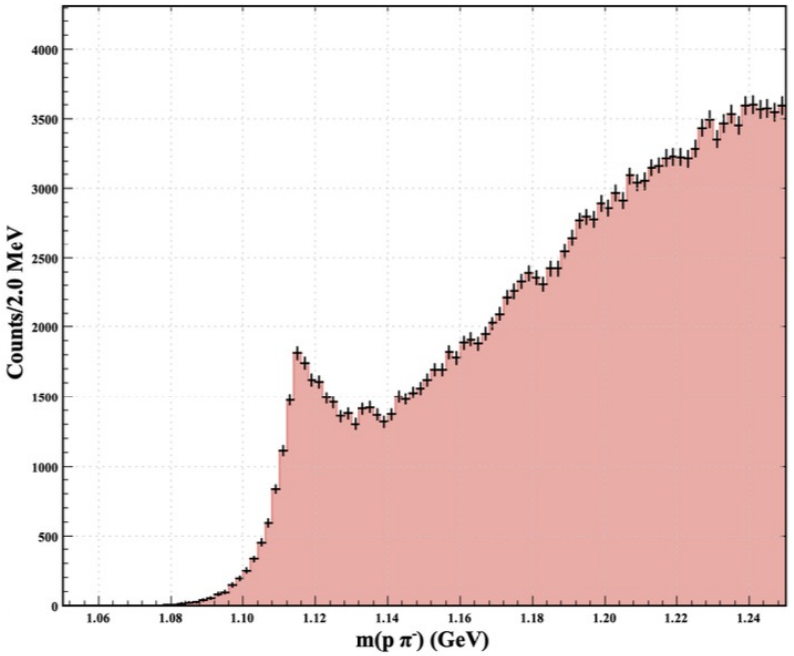
3. Compute r as the distance between the so-obtained doca points of each track



Λ Candidate Skim Selection Criteria (1)

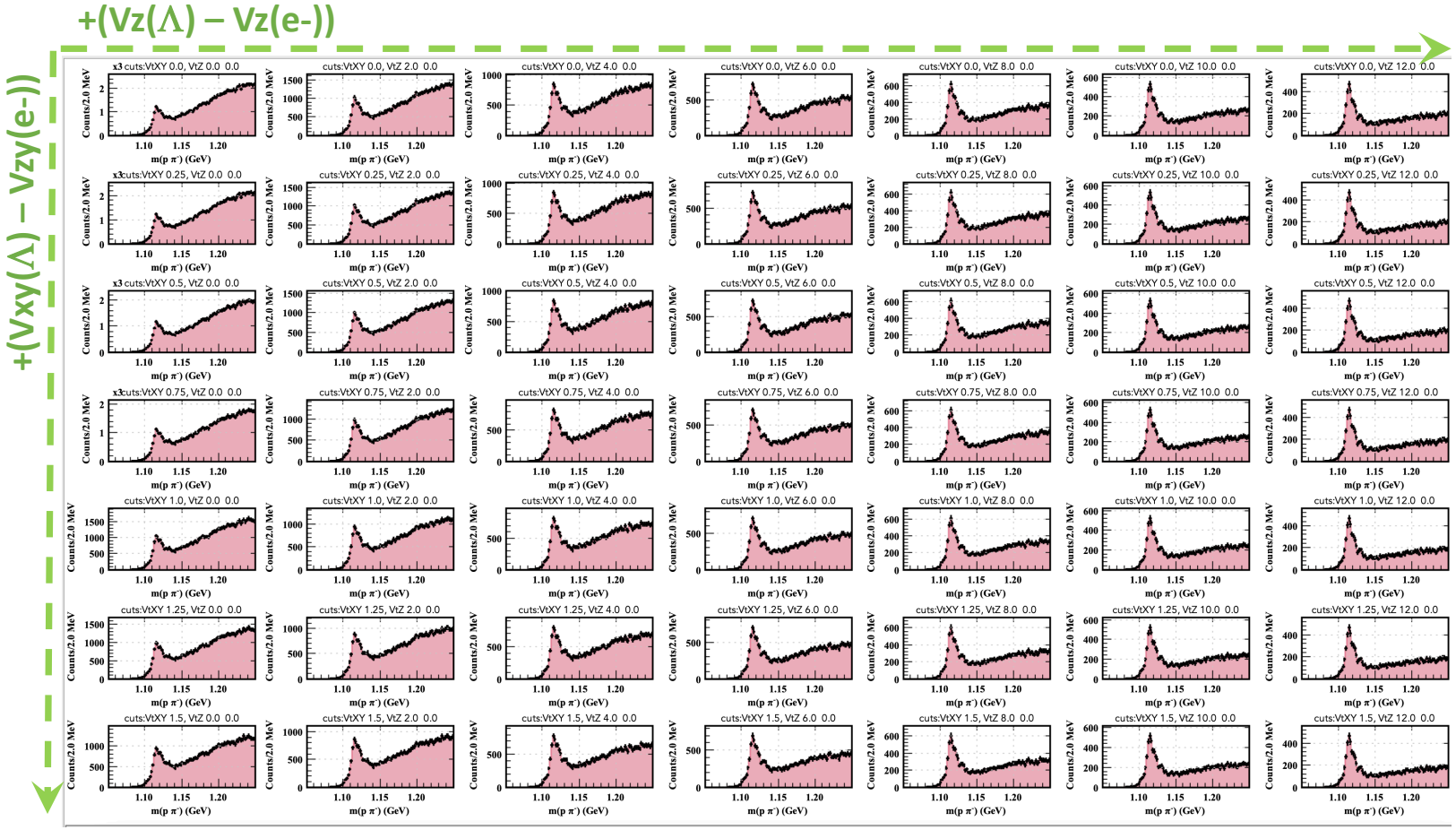
Electro-production data

- Topology: p & π^- in FD: improved resolution and signal-to-background ratio
- 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
- Analysis requirement: Λ vertex to be downstream of the e- vertex (not @skim-level)



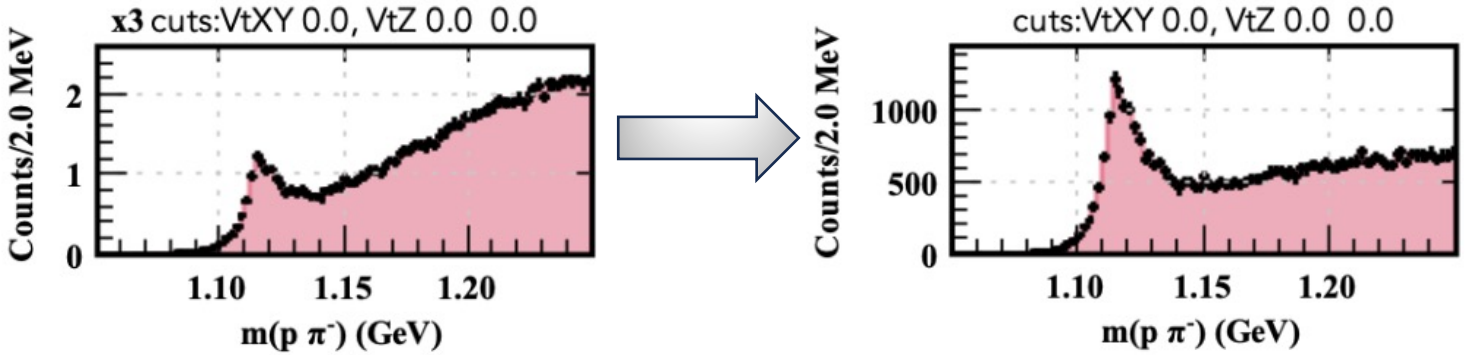
m(pπ-) spectrum for (pπ-) track pairs combined using the common vertex finding algorithm

- Effect of vertex displacement cuts
  - longitudinal vertex displacement (wrt e− vertex) cuts (dz) in increments of 2.0 cm (from 0 to 12.0 cm) from left to right on the horizontal axis
  - values of the transverse vertex displacement cuts (dxy) in increments of 0.25 cm (from 0 to 1.5 cm) from top to bottom on the vertical axis

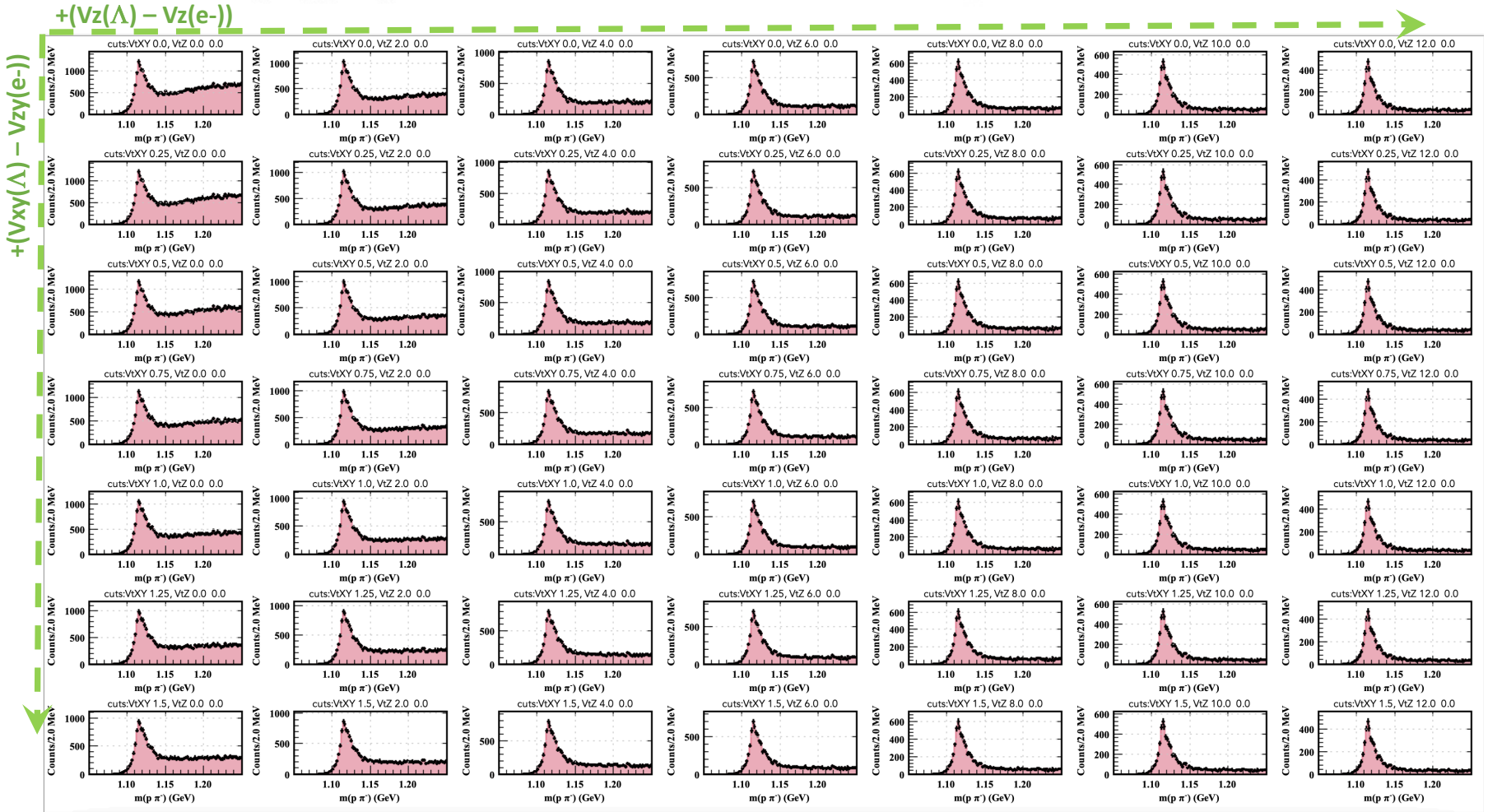


Λ Candidate Skim Selection Criteria (2)

- Require the cosine of the angle between the proton and pion computed assuming the Λ PDG mass between +/- 1

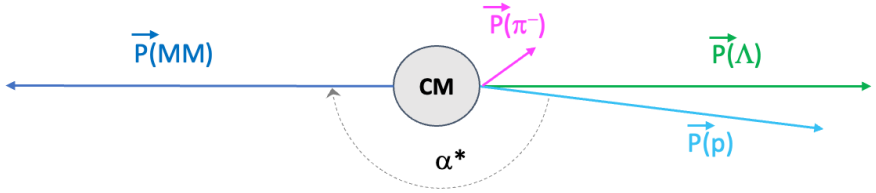


- With of vertex displacement cuts

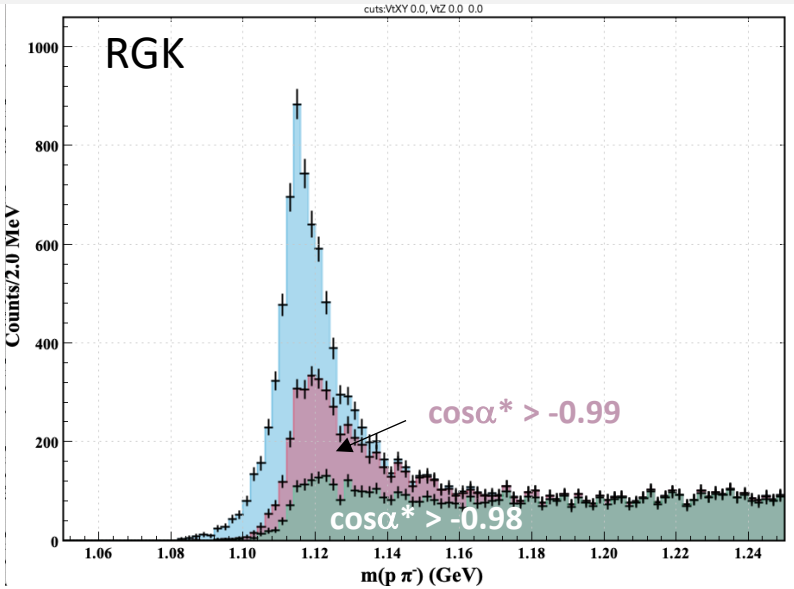


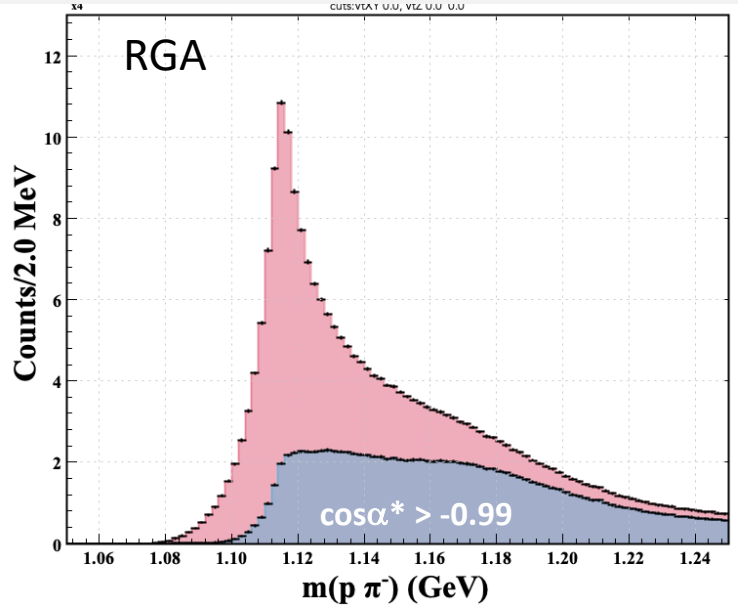
Λ Candidate Analysis Selection Criteria

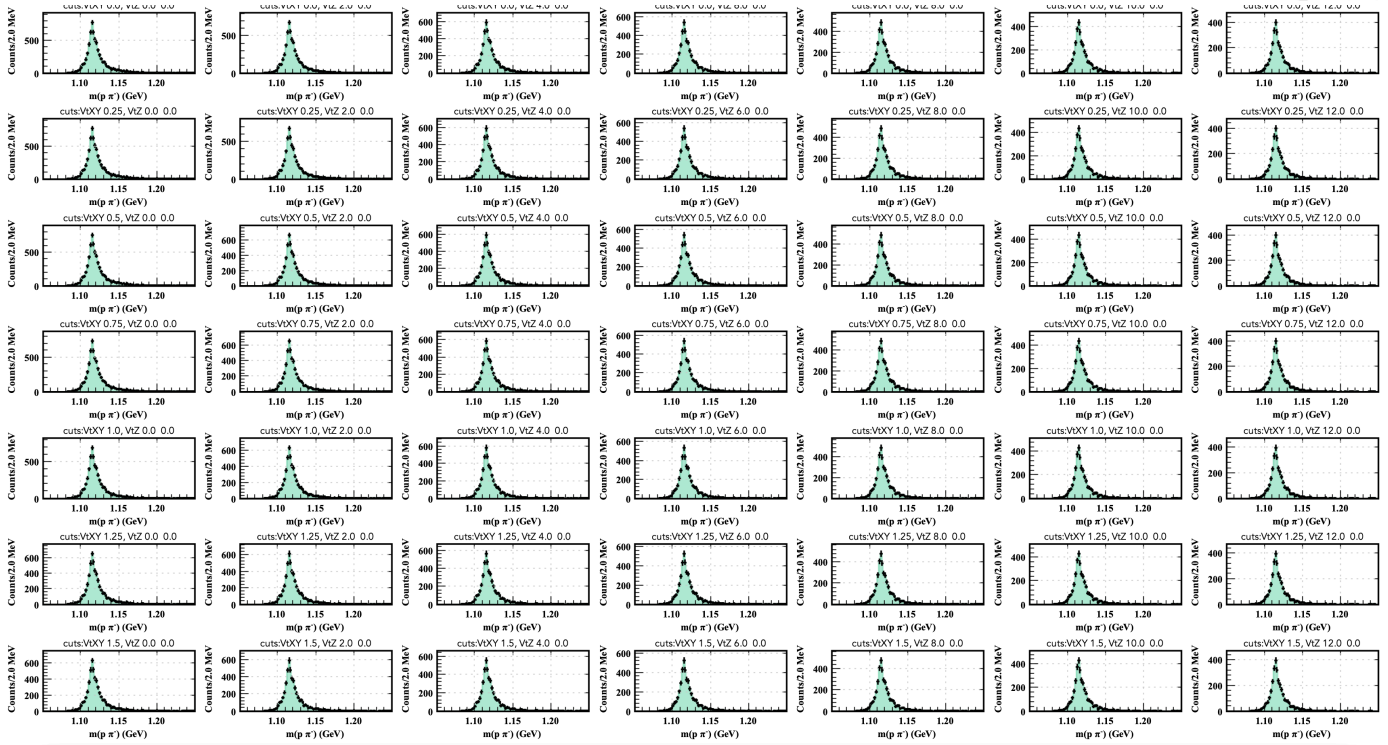
- **Selection applied on skimmed events**
  - Angular cut: cosα* = angle between $\vec{P}(p)$ and $\vec{P}(MM)$ in CM-frame



- Require cosα* < -0.98 for this dataset
  - Cut optimized based on data set
    - Physics reach (event kinematics), backgrounds, yielding different cut selections
    - With of vertex displacement cuts

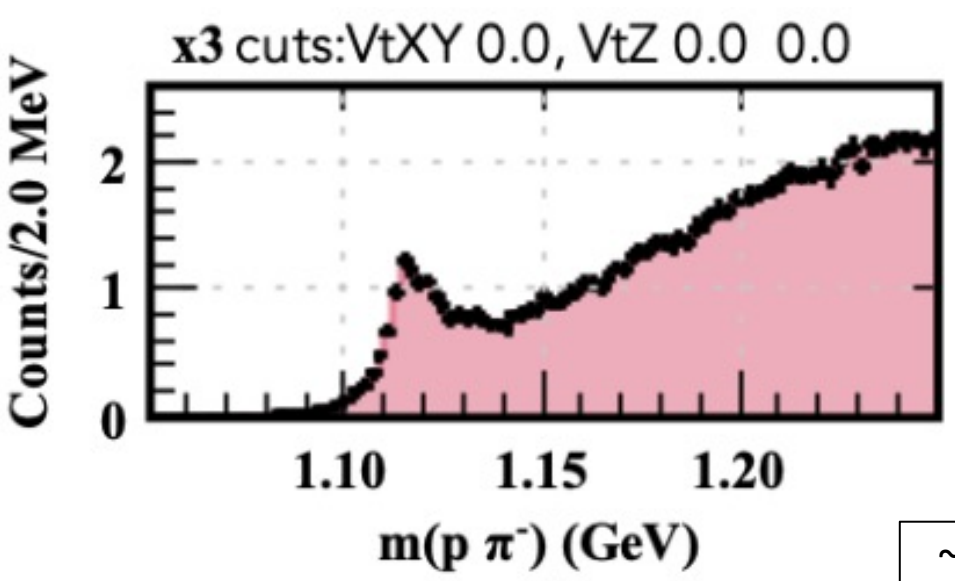


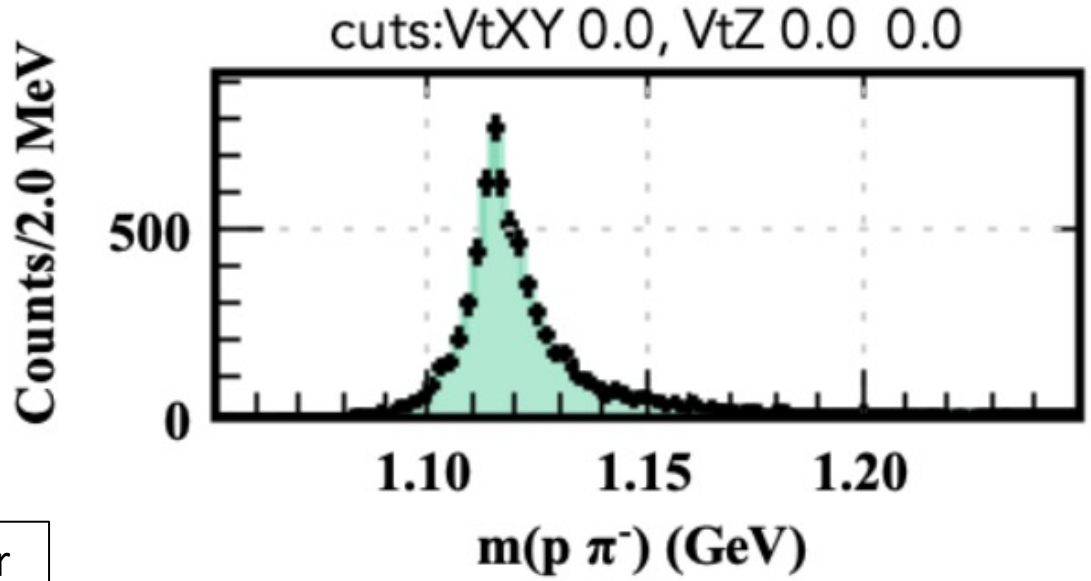




Λ Candidate Skim and Analysis Selection Criteria

- Topology: p & π^- in FD: improved resolution and signal-to-background ratio
- 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
- Λ vertex to be downstream of the e- vertex (not @skim-level)
- Require the cosine of the angle between the proton and pion computed assuming the Λ PDG mass between +/- 1 (@skim level)
- cosα* < -0.98 (not @skim level)





~ no loss in number of signal events

Skim Data Processing

- Skim runs as a service on dst's → output bank, YAML settings

idx: the index of the particle: starting at 100 for the Λ candidate; corresponds to the row (starting at 1) in the REC::Particle bank for the proton and pion;

pid: the pid of the particle using the LUND convention;

emc: the mass-constrained energy;

erec: the reconstructed energy;

e: the energy used in the analysis (mass-constrained);

ovx: the parent vertex $x-$component (the e- vertex is used for the Λ;

ovy: the parent vertex $y-$component;

ovz: the parent vertex $z-$component

px: the particle momentum $x-$component at the DOCA;

py: the particle momentum $y-$component at the DOCA;

pz: the particle momentum $z-$component at the DOCA;

px: the uncorrected momentum $x-$component;

py: the uncorrected momentum $y-$component;

pz: the uncorrected momentum $z-$component;

r: the DOCA between the proton and pion tracks;

vx: the particle vertex $x-$component at the DOCA;

vx: the particle vertex $y-$component at the DOCA;

vx: the particle vertex $z-$component at the DOCA;

charge: the particle charge;

mass: the mass obtained by 4-momentum addition using e and px, py, pz;

ndau: the number of daughters;

dau1idx : the index of the first daughter (p) corresponding to the row in the REC::Particle bank;

dau2idx : the index of the second daughter (π^-) corresponding to the row in the REC::Particle bank;

det : the detector (FD=1, CD=0) where the track is reconstructed.

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    name: MAGFIELDS
  - class: org.jlab.clas.analysis.AnalysisEngine
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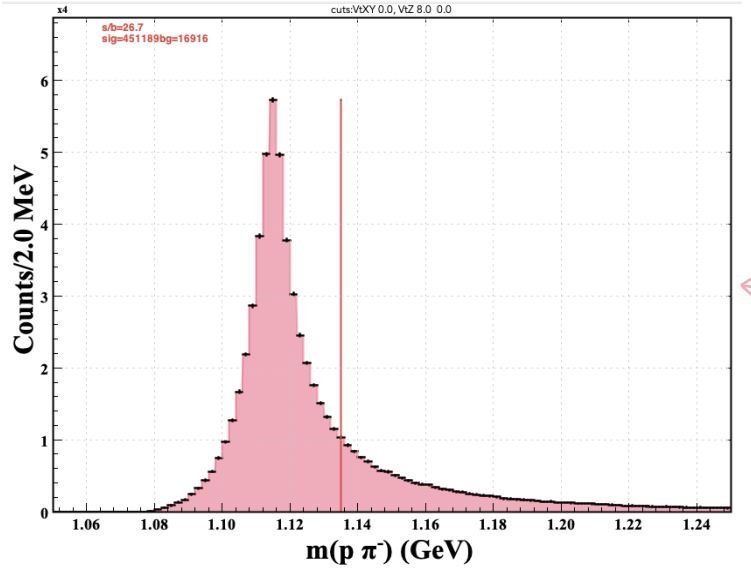
Combining Selected Λ with another Particle

RGA Pass-2 Data



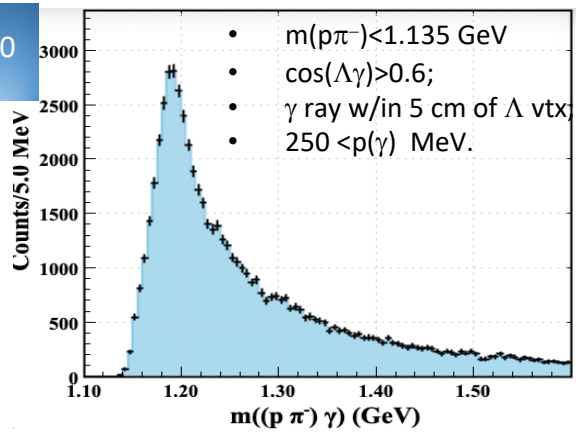
+ γ

+ π^0

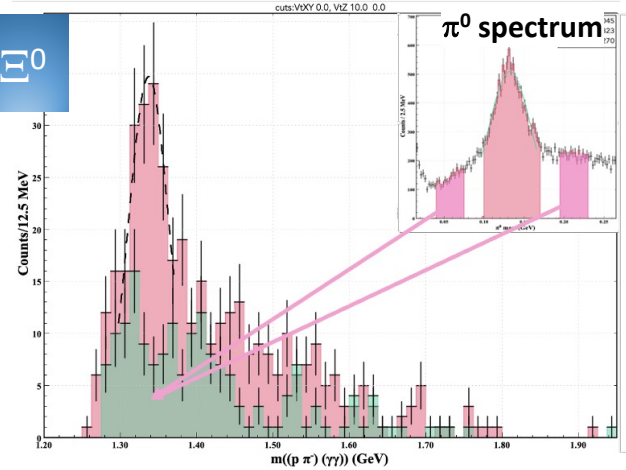
+ π^+

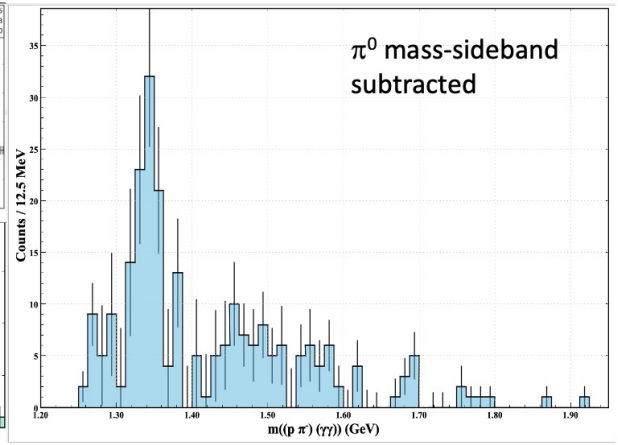
Σ^0

- m(pπ⁻)<1.135 GeV
- cos(Λγ)>0.6;
- γ ray w/in 5 cm of Λ vtx
- 250 <p(γ) MeV.



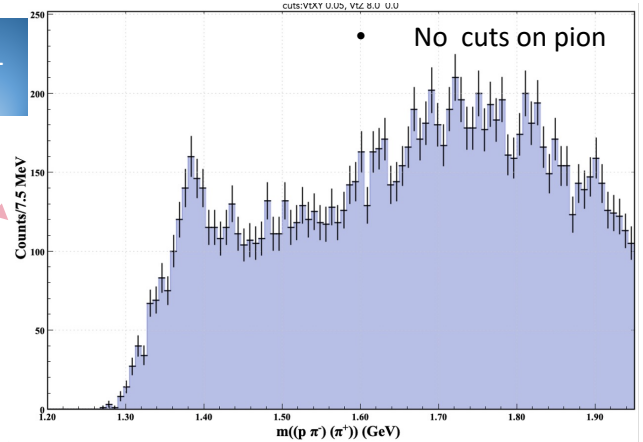
Ξ^0





Σ^+

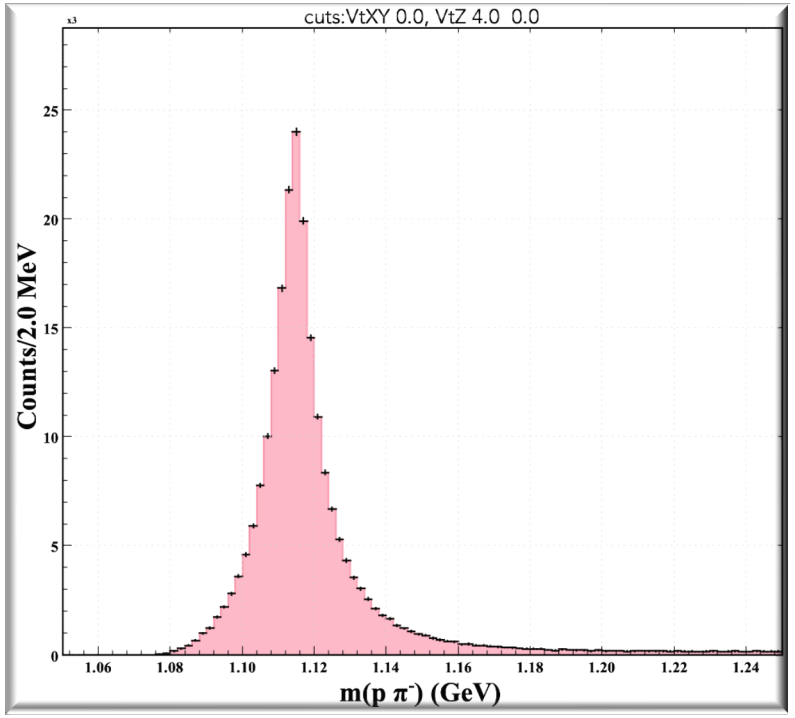
- No cuts on pion

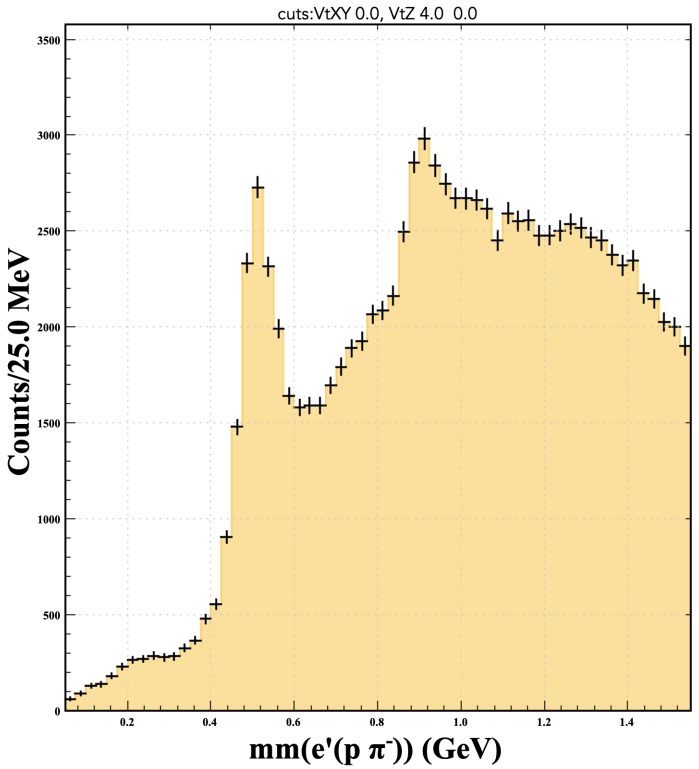


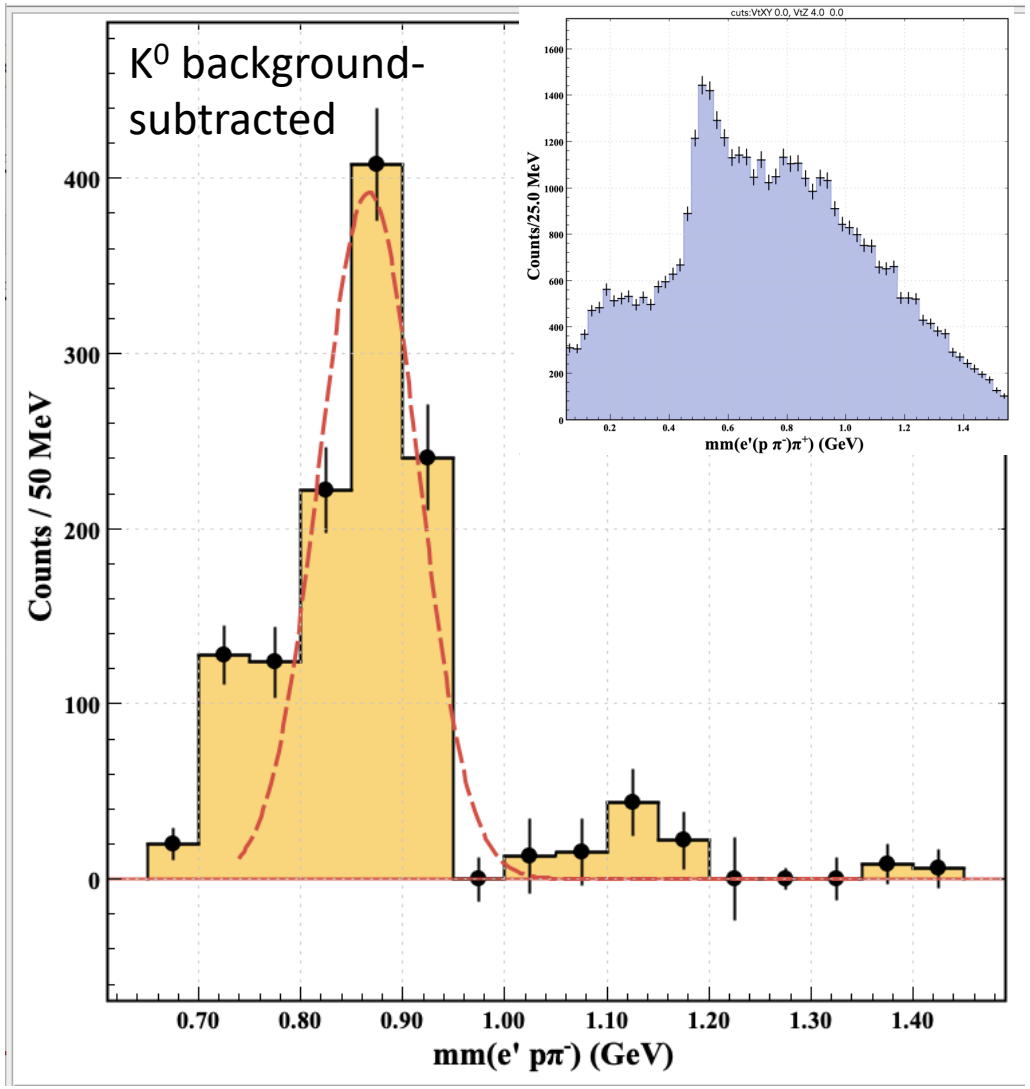
Preliminary Analyses Highlights (1)

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

- Clean Λ spectrum ➔ reduces background in extraction of physics observables from misreconstructed Λ candidates





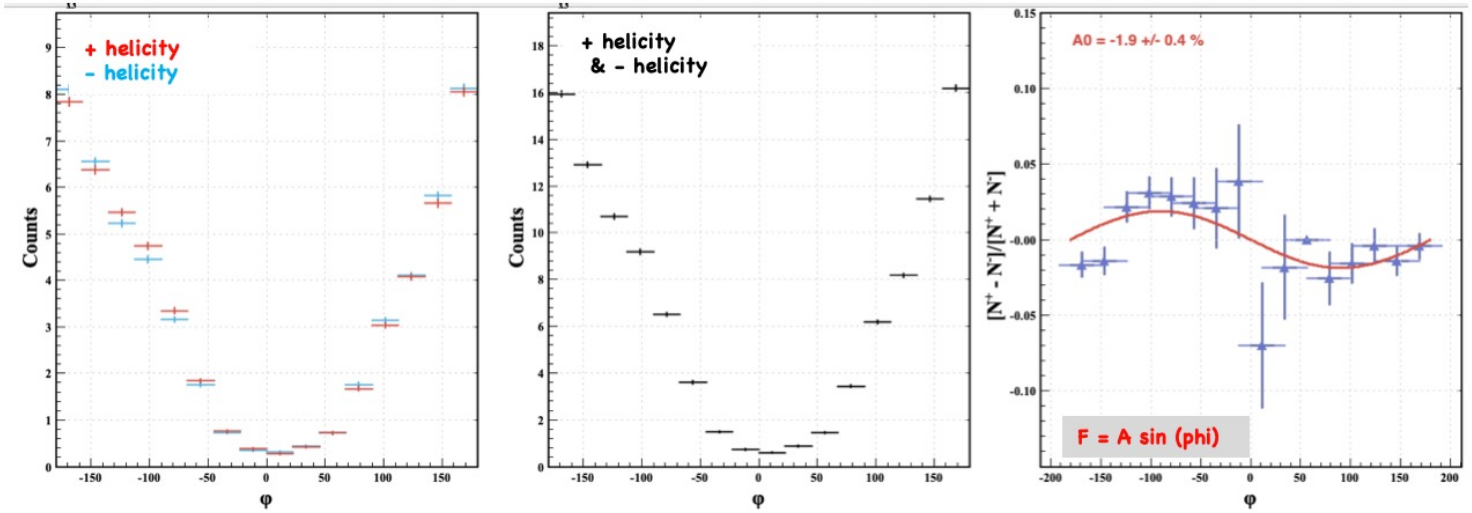


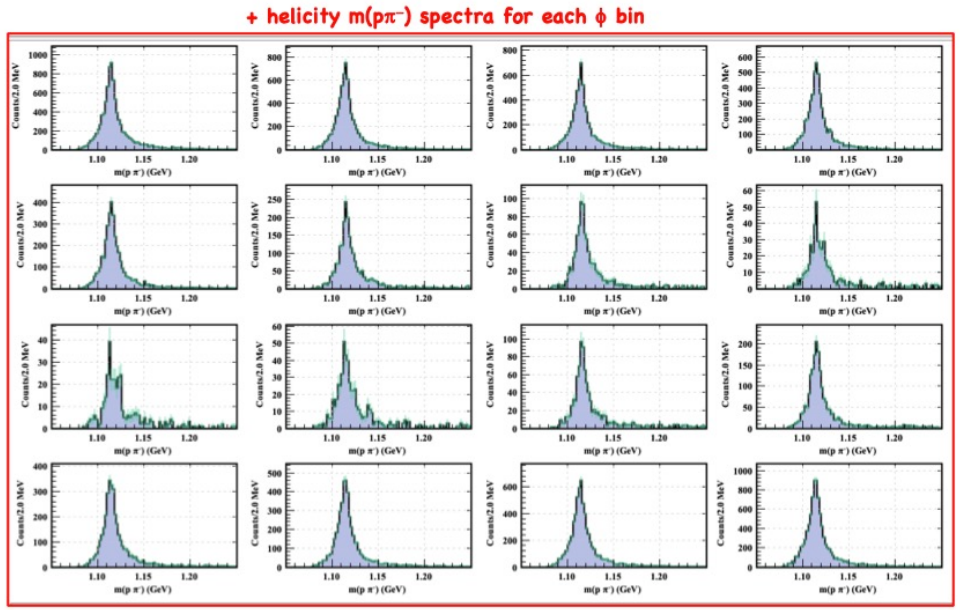
- Details → next talk

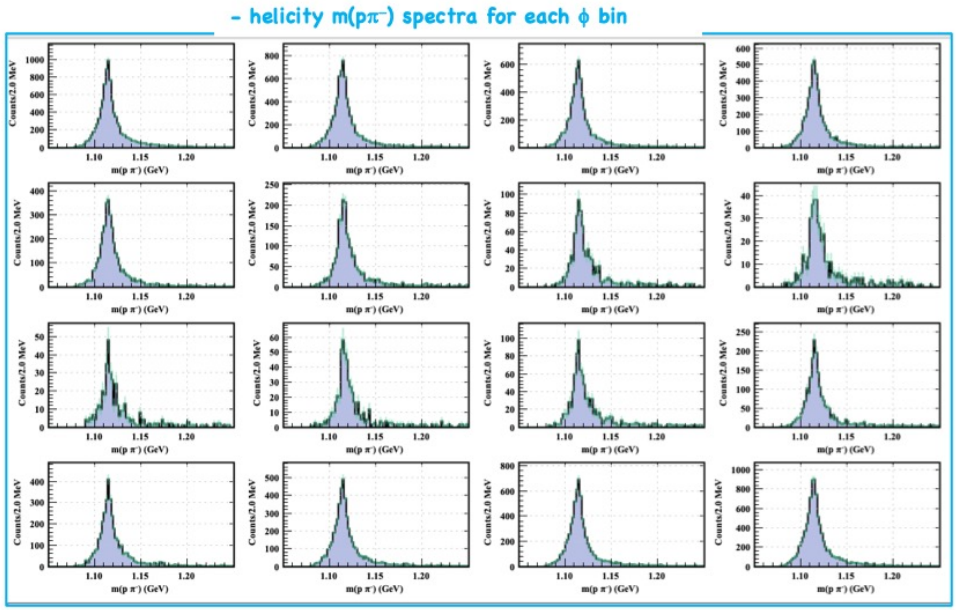
Preliminary Analyses Highlights (2)

BSA Studies using RGA Pass-2 Fall-18 Data

- Very clean Λ distributions for all ϕ bins → no need for background subtraction







- Details → talk at Deep Processes session yesterday

Summary

- Λ skim in production
  - Ongoing effort to include it in trains
- Λ selection criteria yield very good signal purity
- Λ skim used for several analysis
  - Can do analyses too challenging to perform using the missing mass technique (e.g. ΛK* final state)
- CLAS12 Note available
  - https://misportal.jlab.org/mis/physics/clas12/viewFile.cfm/2024-008.pdf?documentId=174

Outlook

- Semi-exclusive Λ skim allows analyses of multibody decays (e.g. ep→eΛK^{*+}(→$K^+\pi^-$)) and sequential decays to a Λ with more precision than by the missing mass technique
- Several analyses with Λ skim
  - BSA
  - Induced polarization studies
  - Searches for strange baryons decaying to a Λ
  - Study of the recoil against $\Xi^0 \rightarrow \Lambda\pi^0$ ➔search for τ^+ tetraquark state
  - Λ SIDIS production off nuclei with RGE data(→**Uditha Weerasinghe** U. MISS)
- Some analyses do not belong to a single working group (e.g. very strange+deep processes)
  - Should we form a group dedicated to semi-exclusive Λ analyses ?
    - What other analyses could be carried out using the Λ skim?
    - Analyses techniques
    - Simulations, trains for various Run Groups
    - Momentum corrections (effect on Λ peak position)
    - Data quality assessment for new runs
  - Interest from different Run Groups?

BACKUP SLIDES

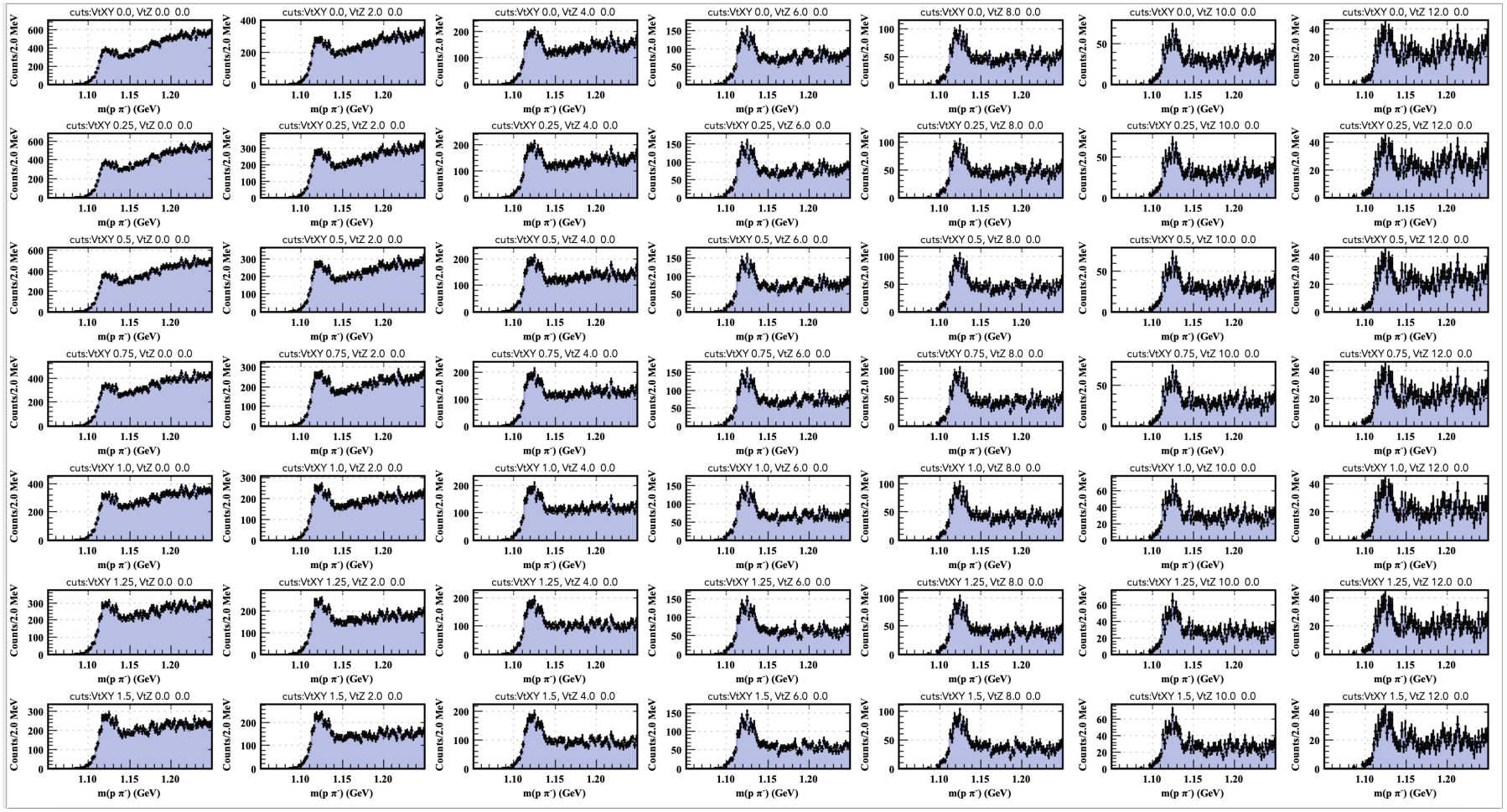


Figure 9: Reconstructed $m(p\pi^-)$ distributions as a function of the $\Lambda \to p\pi^-$ vertex displacement cuts for $||\, cos\alpha < 1$ and the pion reconstructed in the CD.