CLAS12 Collaboration Meeting

March 14, 2024

A Search for the Ω^- Baryon in RGA Data

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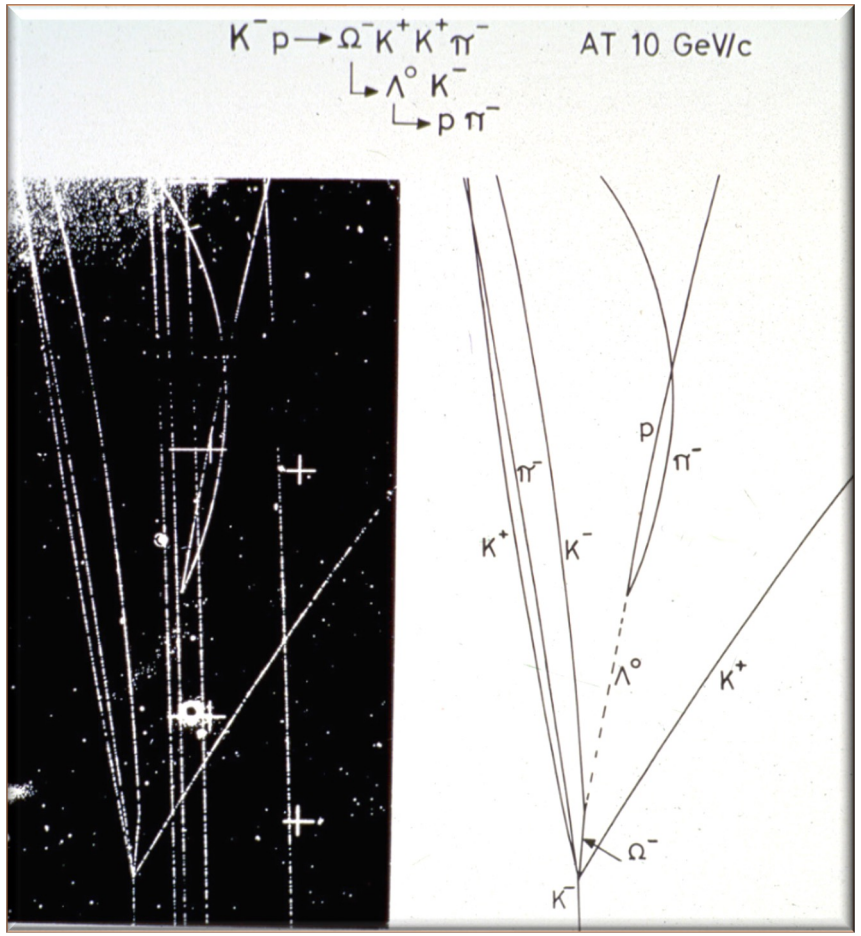


CERN liquid hydrogen bubble chamber
CERN-EX-41769

Motivation and Search Strategy

- **Motivation**
  - Part of the *very* strange proposal
  - Not seen in electroproduction → would constitute a first observation

- **Strategy**
  - Search for Ω^- production in $e^- p \rightarrow e^- (\Lambda K^-) X$ events
    - Exclusive $\Lambda \rightarrow p\pi^-$ reconstruction using vertex displacement selection criteria to improve the purity of the Λ signal
  - 4-momentum addition of selected $\Lambda \rightarrow p\pi^-$ signal candidates with a K^-
    - Strangeness conservation → MM($e^- \Lambda[\rightarrow p\pi^-] K^-$) above 3 kaon-mass threshold (w/in resolution)

Event Selection

RGA (e-in EC, FT)

- Selection of ep→ e ($p\pi^-$) K^- X events using Fall18 (in- and out-bending) + Spring19 Pass-2 RGA data
  - Select events with at least one electron (for start time, in EC or FT), one proton, one pi- and one K-
  - 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
  - e- reconstructed in EC (EC sample)
  - e- reconstructed in FT (FT sample)
  - K^- id given by the EB
    - PID cuts (reconstructed kaon mass) to clean up the sample
  - Require the vertex between p and π^- to be reconstructed with doca<5 cm
  - Use of vertex displacement cuts (of Λ vertex wrt to K- vertex) in XY and Z components
  - Proton pt > 500 MeV
- MM(e^- p π^- K^-) > 1.35 GeV (expect at least 2 K^+'s and a K^0 in the event) for Ω^- production (strangeness conservation)
- TFR, x_F<-0.1 (→ improved Λ signal purity in expected Ω^- → ($p\pi^-$) K^- signal region)

Reconstructed m(p π^-) spectrum for MM region ***above*** the Ω^- production threshold (1.35 GeV)

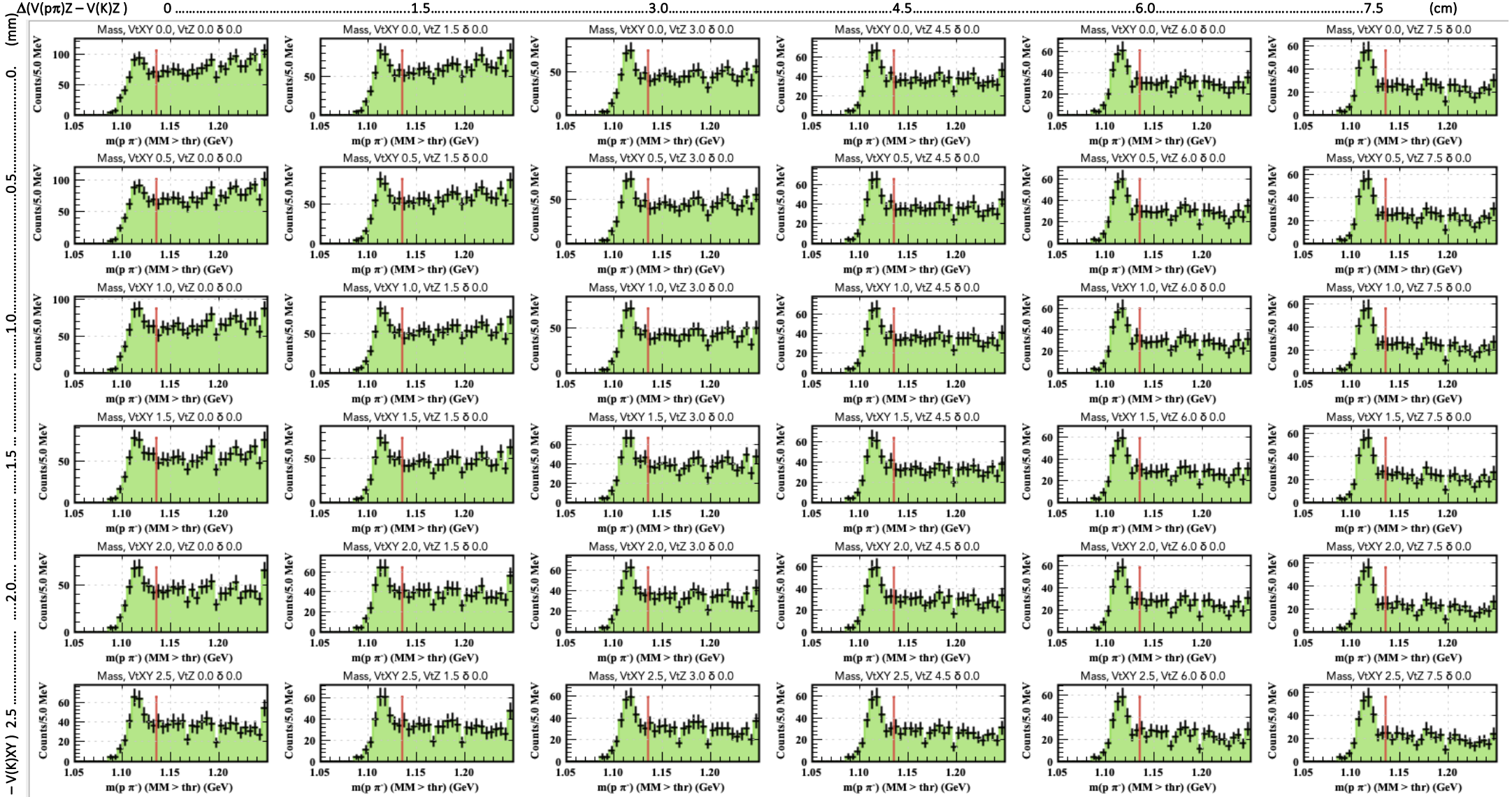
m(p π^-) as a function of vtx cuts (π^- in FD; p in FD; K^- in CD or FD)

- Observed Λ signal

- signal significance increasing with vtx displacement cuts

  - Horizontal axis increase in longitudinal vtx displacement (left to right)
  - Vertical axis increase in transverse vtx displacement (top to bottom)
  - Same convention in all such plots

No cut on m(p π^- K^-), MM > 1.35 GeV

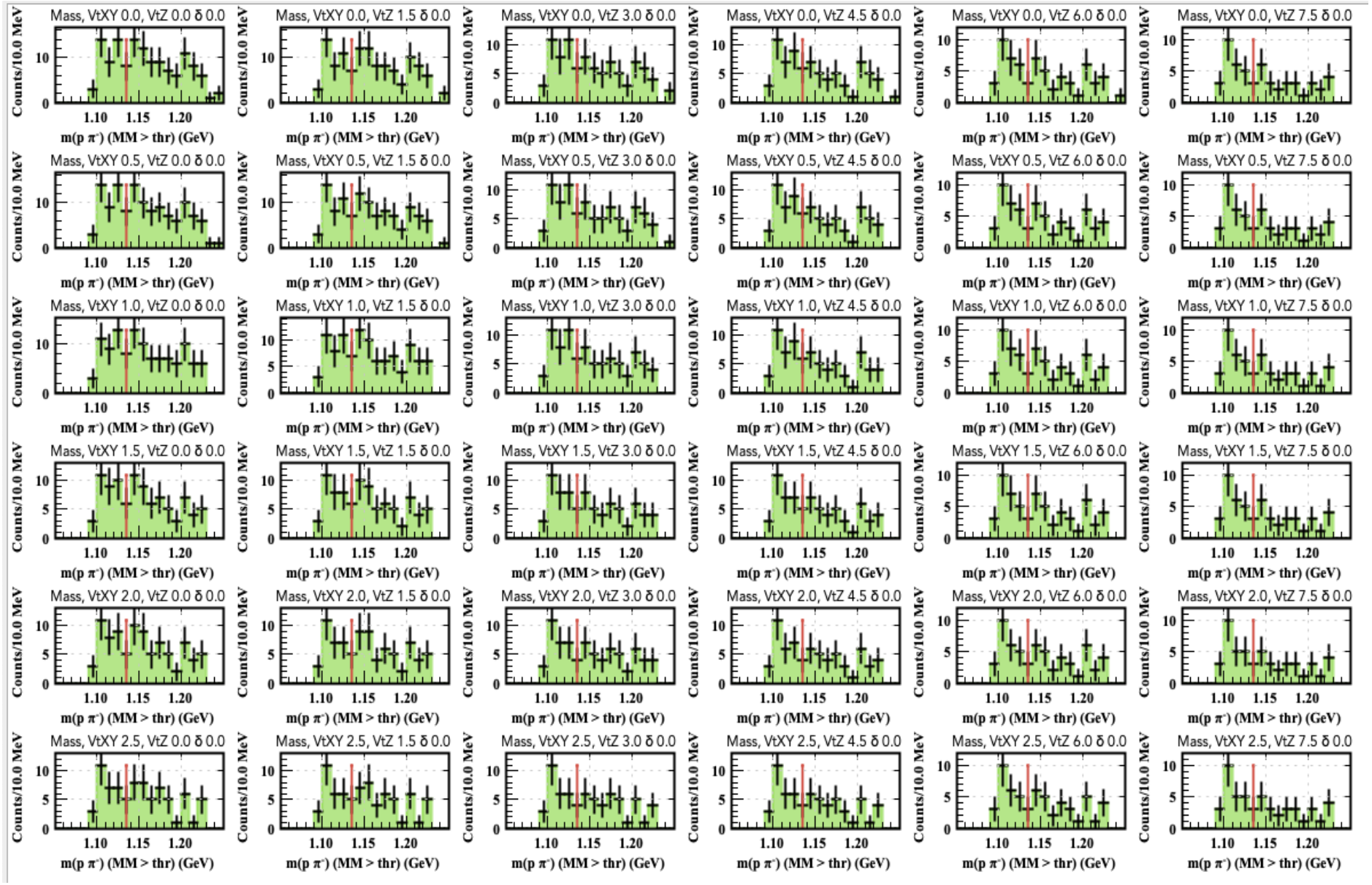


Reconstructed m(p π^-) spectrum for MM region ***above*** the Ω^- production threshold (1.35 GeV) in the expected Ω^- signal region

m(p π^-) as a function of vtx cuts (π^- in FD; p in FD; K^- in CD or FD)

- Study of correlation between to Ω expected Λ signal yield
- Evidence of Λ signal for the Ω^- expected signal region seen with higher vtx cuts

m(p π^- K^-) < 1.75 GeV , MM > 1.35 GeV



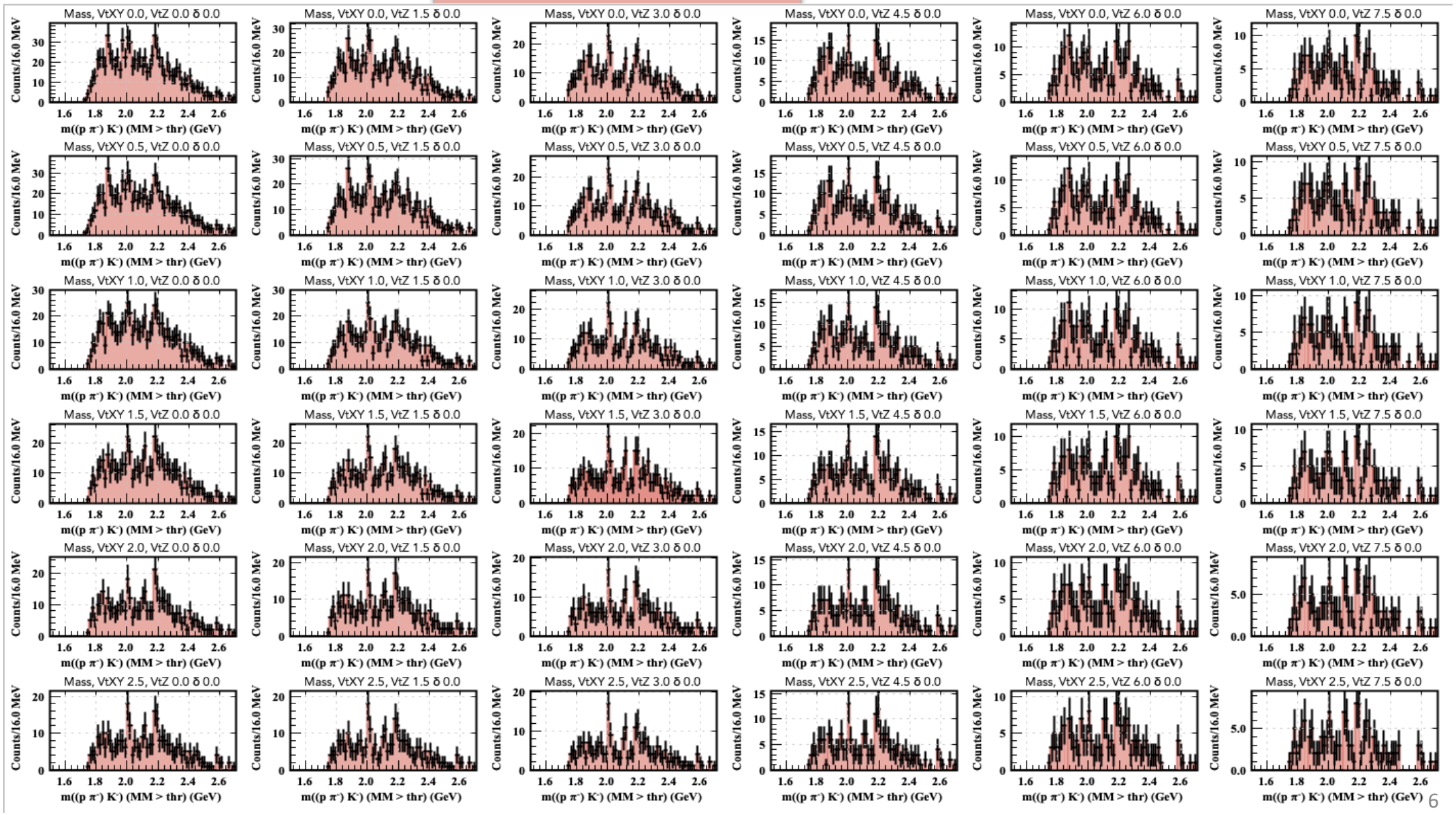
Reconstructed m((p π^-) K^-) spectrum corresponding the Λ sideband region

m(p π^- K^-) as a function of vtx cuts (π^- in FD; p in FD; K^- in CD or FD)

- ~ uniform background across m(Λ K^-) mass range
- No obvious structures

Λ sideband region
1.185 < m(pπ-) < 1.235 GeV

MM > 1.35 GeV



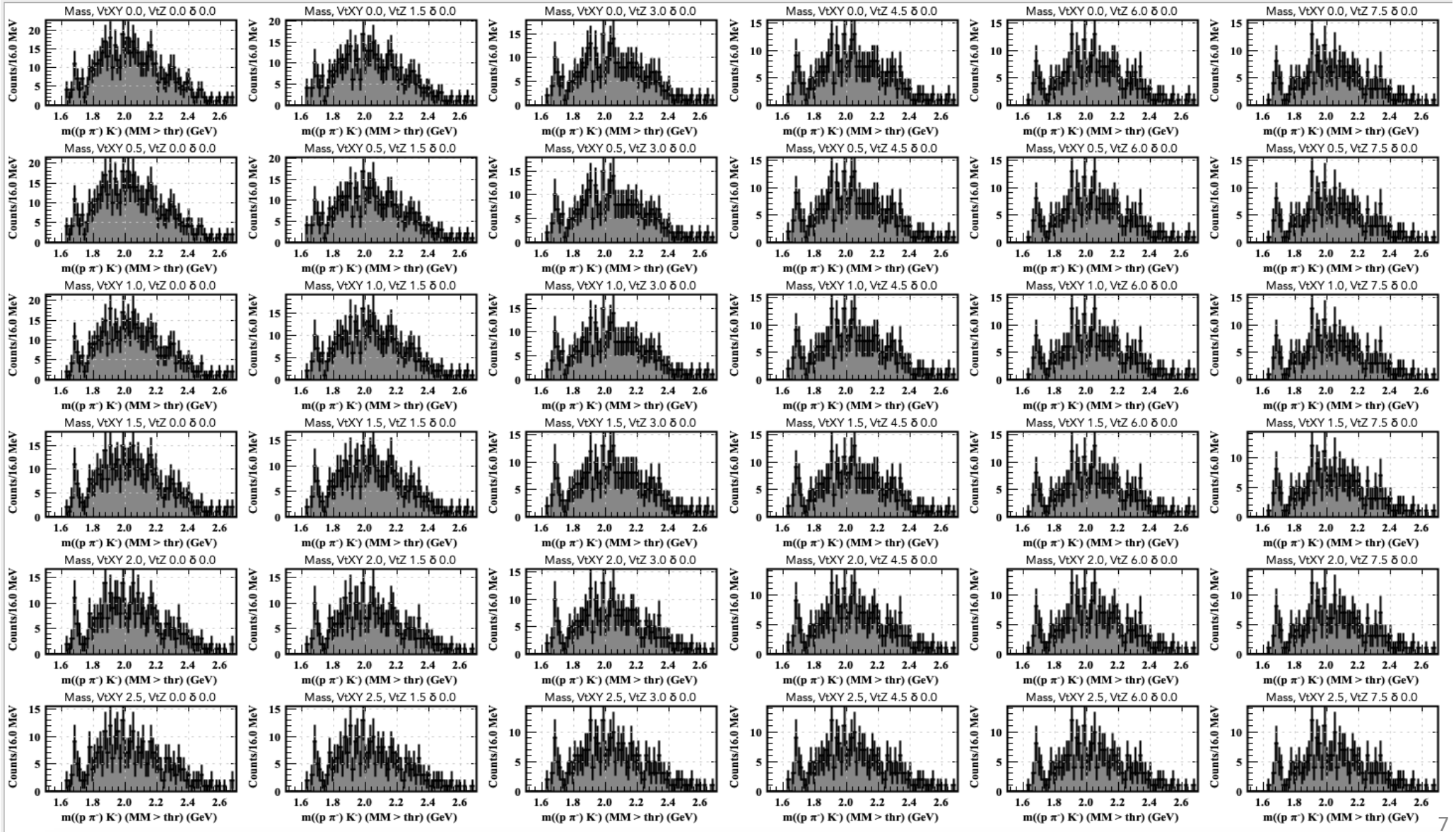
Reconstructed m((p π^-) K^-) spectrum corresponding the Λ signal region

m(p π^- K^-) as a function of vtx cuts (π^- in FD; p in FD; K^- in CD or FD)

- Observed peak ~ expected Ω^- mass near threshold enhanced with vertex displacement cuts

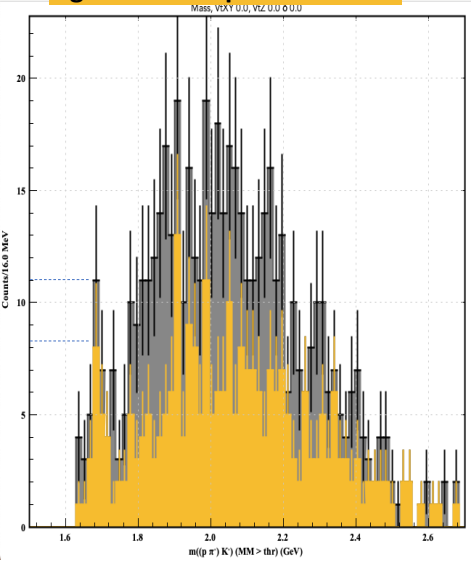
Λ signal region
1.085 < m(p$\pi-$) < 1.135 GeV

MM > 1.35 GeV



Loosest vtx displacement cuts

Tightest vtx displacement cuts



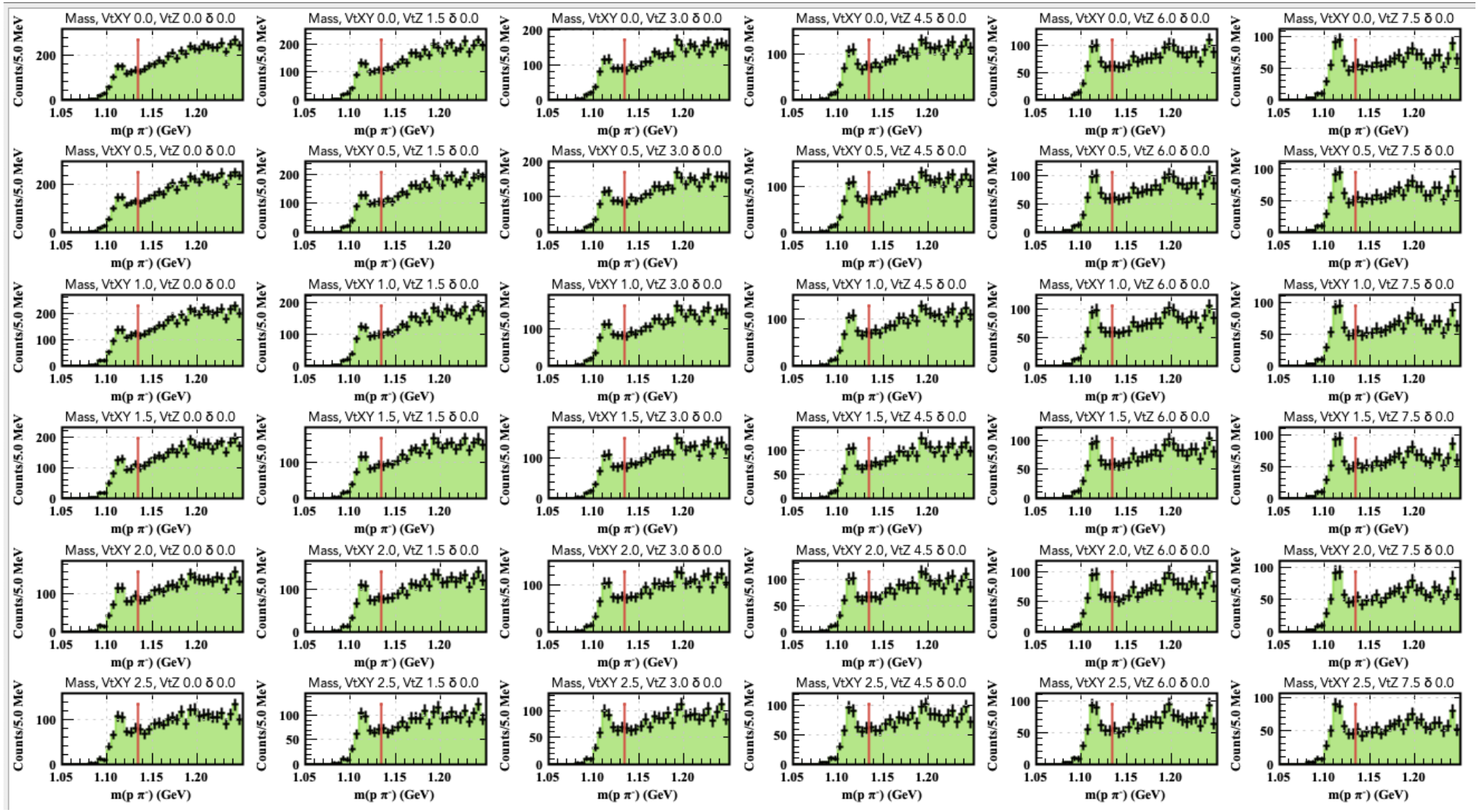
Reconstructed m(p π^-) spectrum for MM region ***below*** the Ω^- production threshold (1.35 GeV)

m(p π^-) as a function of vtx cuts (π^- in FD; p in FD; K^- in CD or FD)

No cut on m(p π^- K^-), MM < 1.35 GeV

- Looking in region of MM in kinematics region where the Ω cannot be produced [i.e. MM < 1.35 GeV] (strangeness conservation)
- Observed Λ signal

✓ Signal significance increasing with vertex displacement cuts

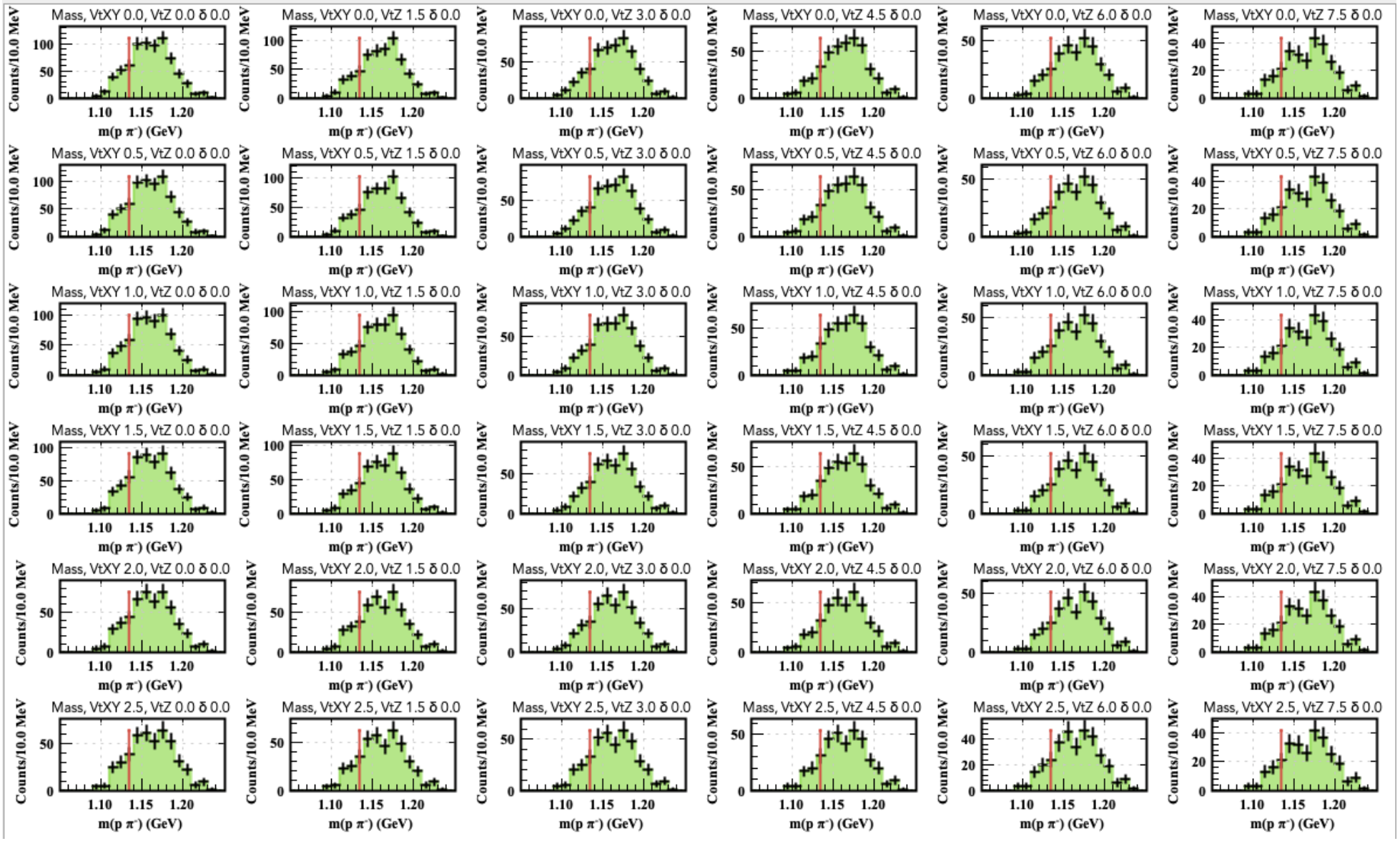


Reconstructed m(p π^-) spectrum for MM region ***below*** the Ω^- production threshold (1.35 GeV) in the expected Ω^- signal region

m(p π^-) as a function of vtx cuts (π^- in FD; p in FD; K^- in CD or FD)

- No evidence of Λ signal corresponding to Ω^- expected signal region

m(p π^- K^-) < 1.75 GeV , MM < 1.35 GeV



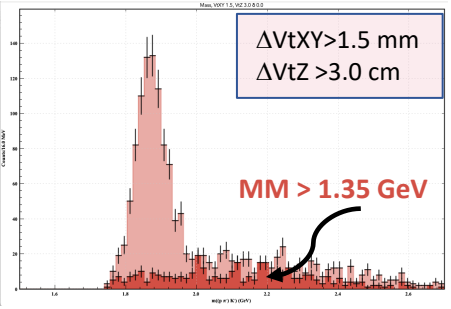
Reconstructed m((p π^-) K^-) spectrum corresponding the Λ mass-sideband region for MM region ***below*** the Ω^- production threshold (1.35 GeV)

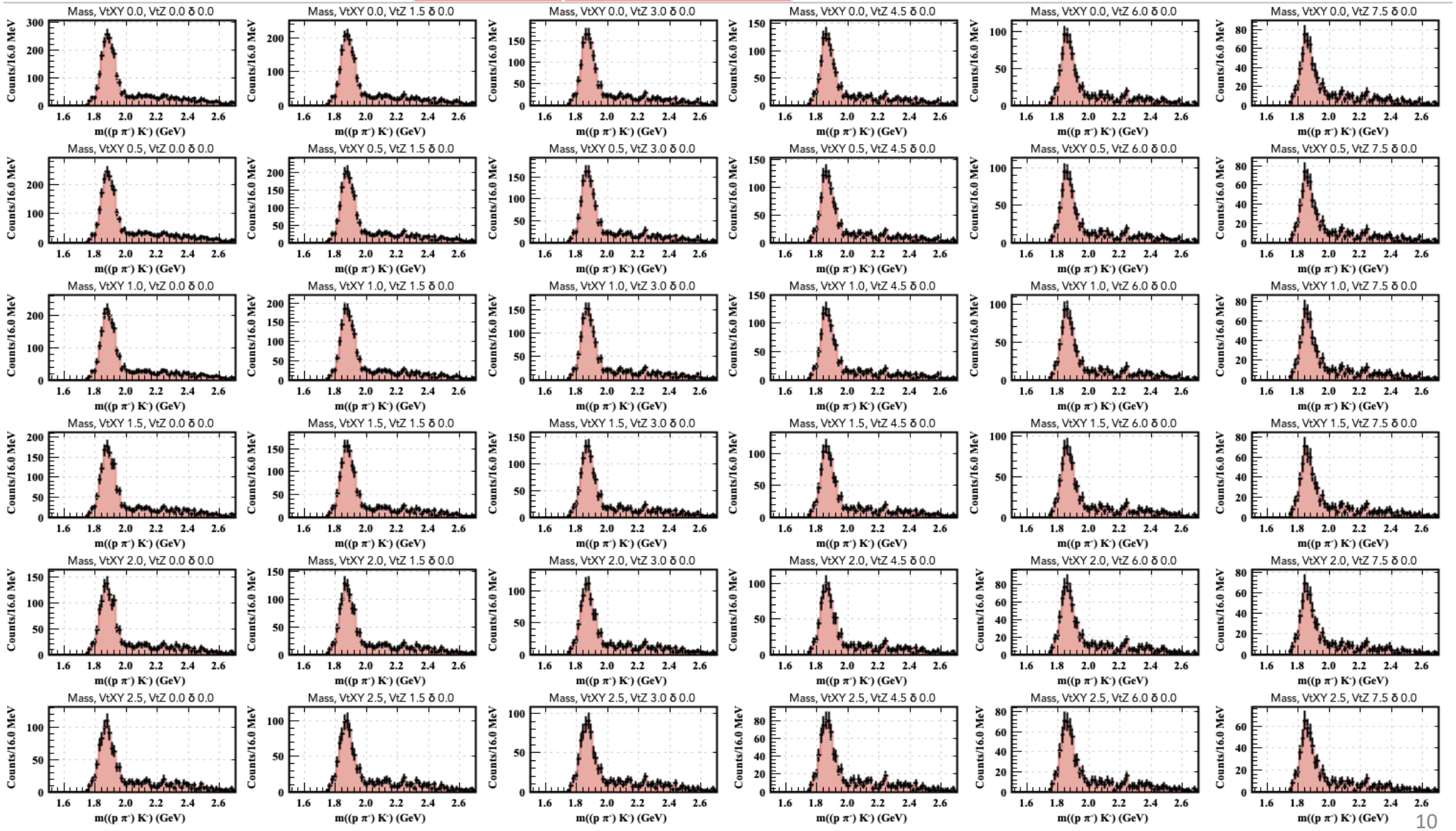
m(p π^-) as a function of vtx cuts (π^- in FD; p in FD; K^- in CD or FD)

- Peaking background near threshold for Λ-mass sidebands

Λ sideband region
1.185 < m(pπ–) < 1.235 GeV

MM < 1.35 GeV





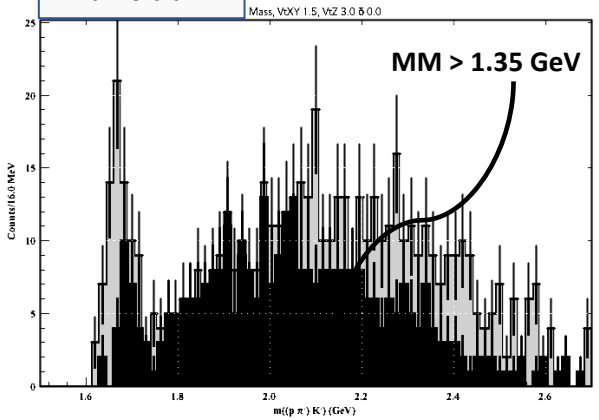
Reconstructed m((p π^-) K^-) spectrum corresponding the Λ signal region for MM region ***below*** 1.35 GeV

- Observed background peak ~below expected Ω signal near threshold - suppressed with vertex displacement cuts

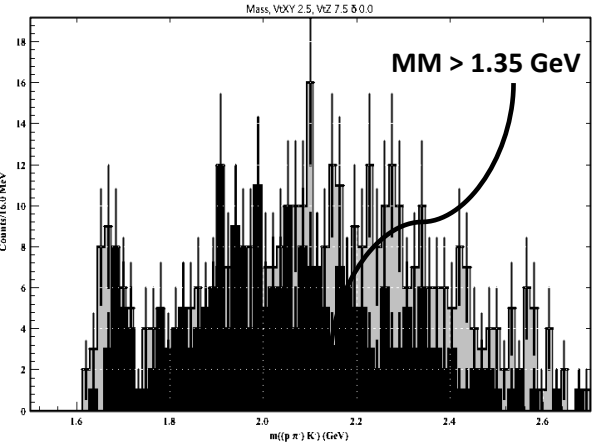
Λ signal region
1.085 < m(pπ-) < 1.135 GeV

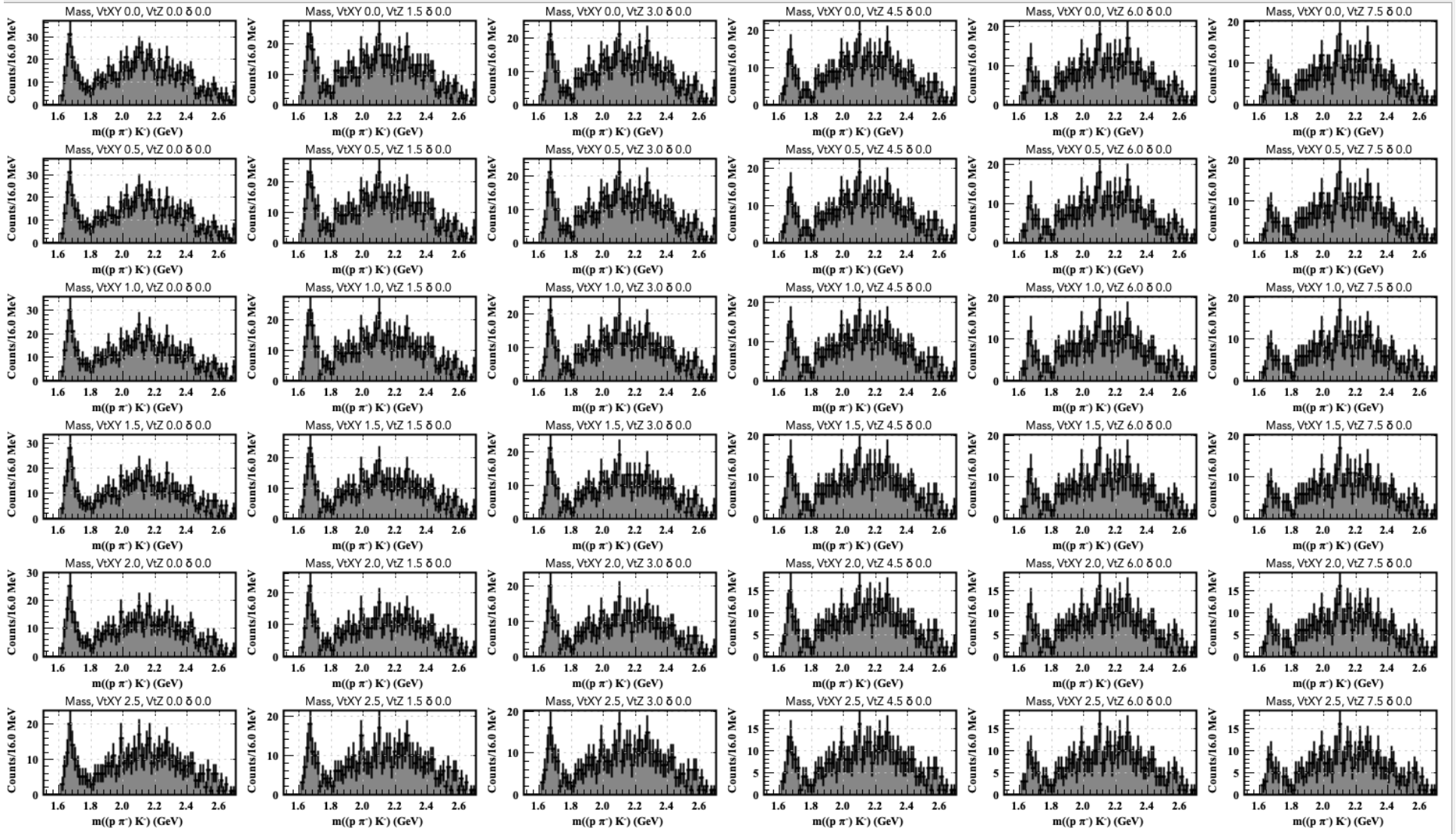
MM < 1.35 GeV

ΔVtXY>1.5 mm
ΔVtZ >3.0 cm



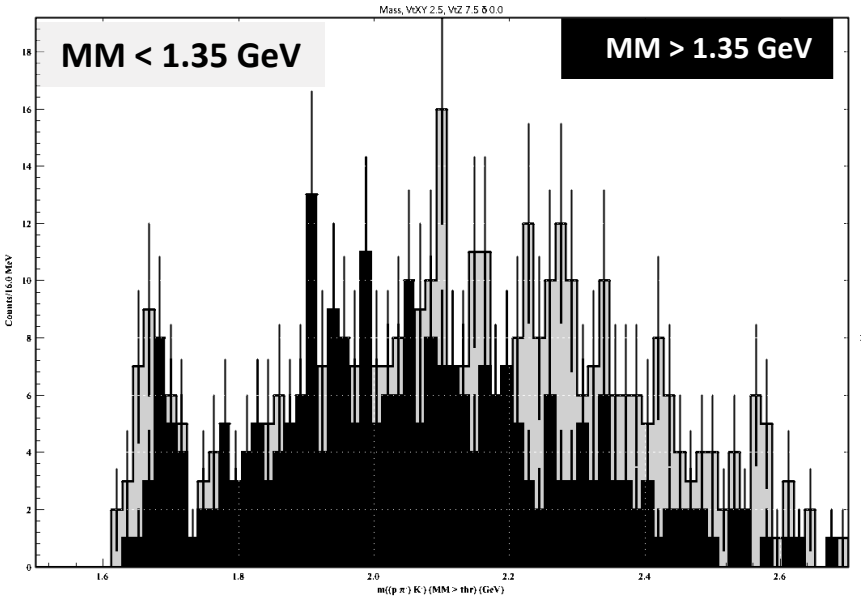
Wth tighter vtx displacement cuts:

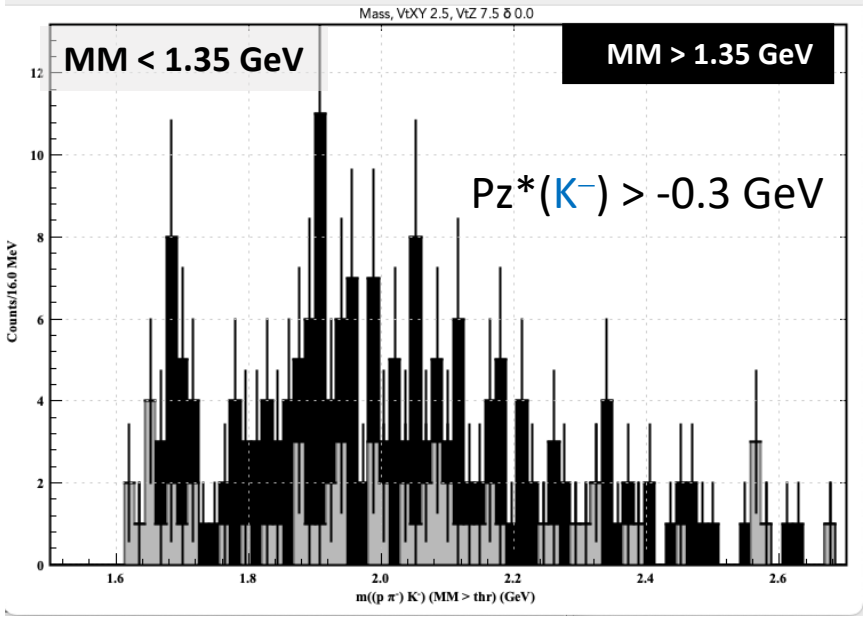




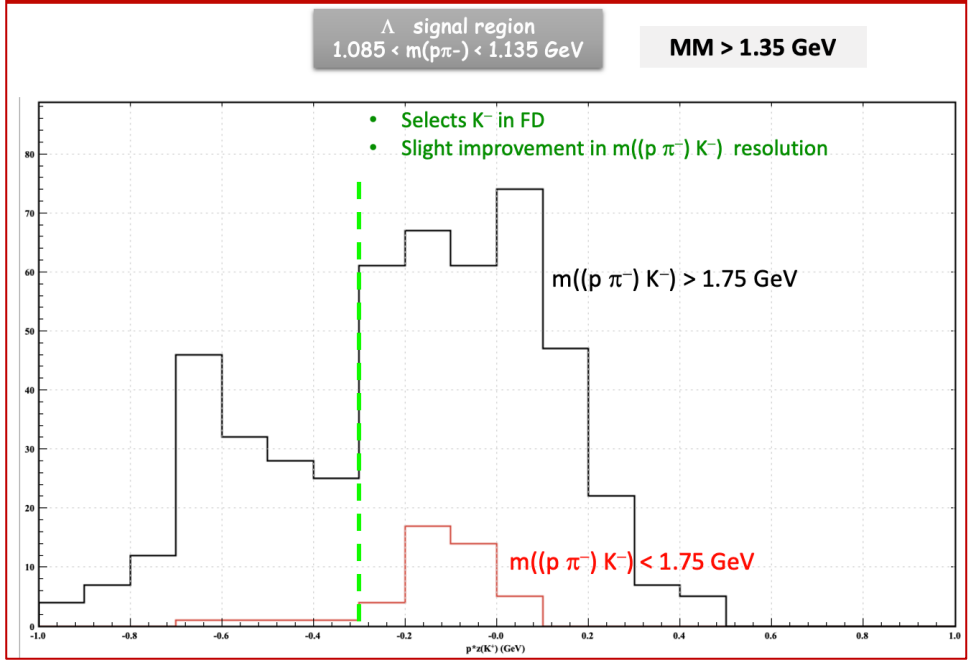
Reconstructed m((p π^-) K^-) spectrum corresponding the Λ signal region for MM region ***below*** and ***above*** 1.35 GeV

- Peak corresponding to MM below Ω^- production region is below the peak corresponding to MM region expected for Ω^- production
- Vertex cuts reduce the peak corresponding to MM below Ω^- production region while retaining most of the peak corresponding to MM region expected for Ω^- production
- P*z(K) cut further suppresses this background





Pz*(K^-) Discriminating Variable



Physics background studies using $e^- p \rightarrow e^- (p\ \pi^-)\ K^+ X$ RGA events

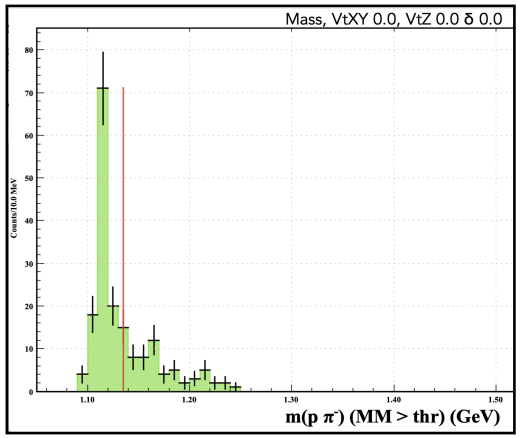
"wrong charge" sample

m((p π^-) K^+) as a function of vtx cuts
(π^- in FD; p in FD; K^- in CD or FD)

- **No obvious peaking background at expected Ω^- signal near threshold**

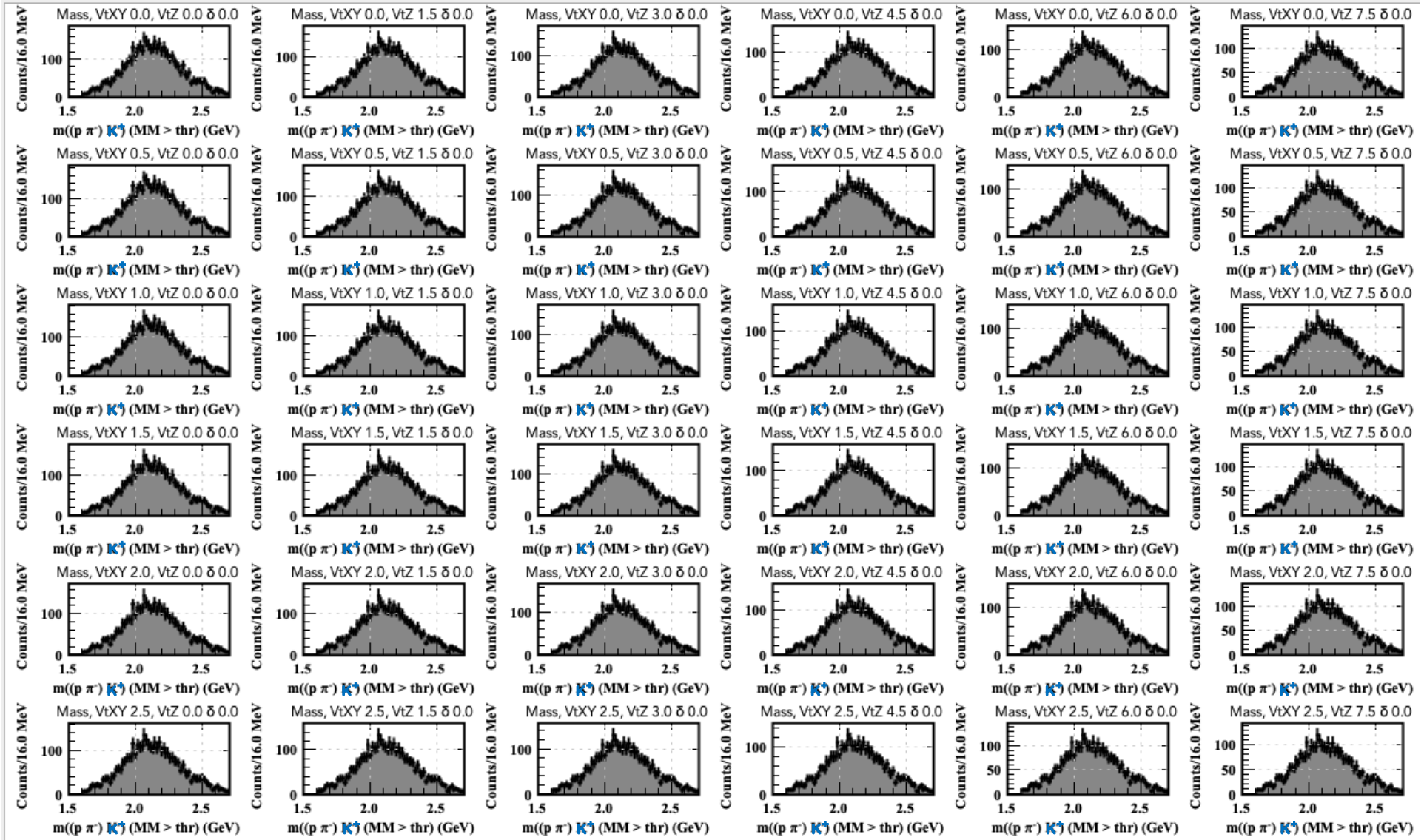
m(p π^- K^+) < 1.75 GeV , MM > 1.35 GeV

- **Clean Λ signal**



Λ signal region
1.085 < m(pπ-) < 1.135 GeV

MM > 1.35 GeV



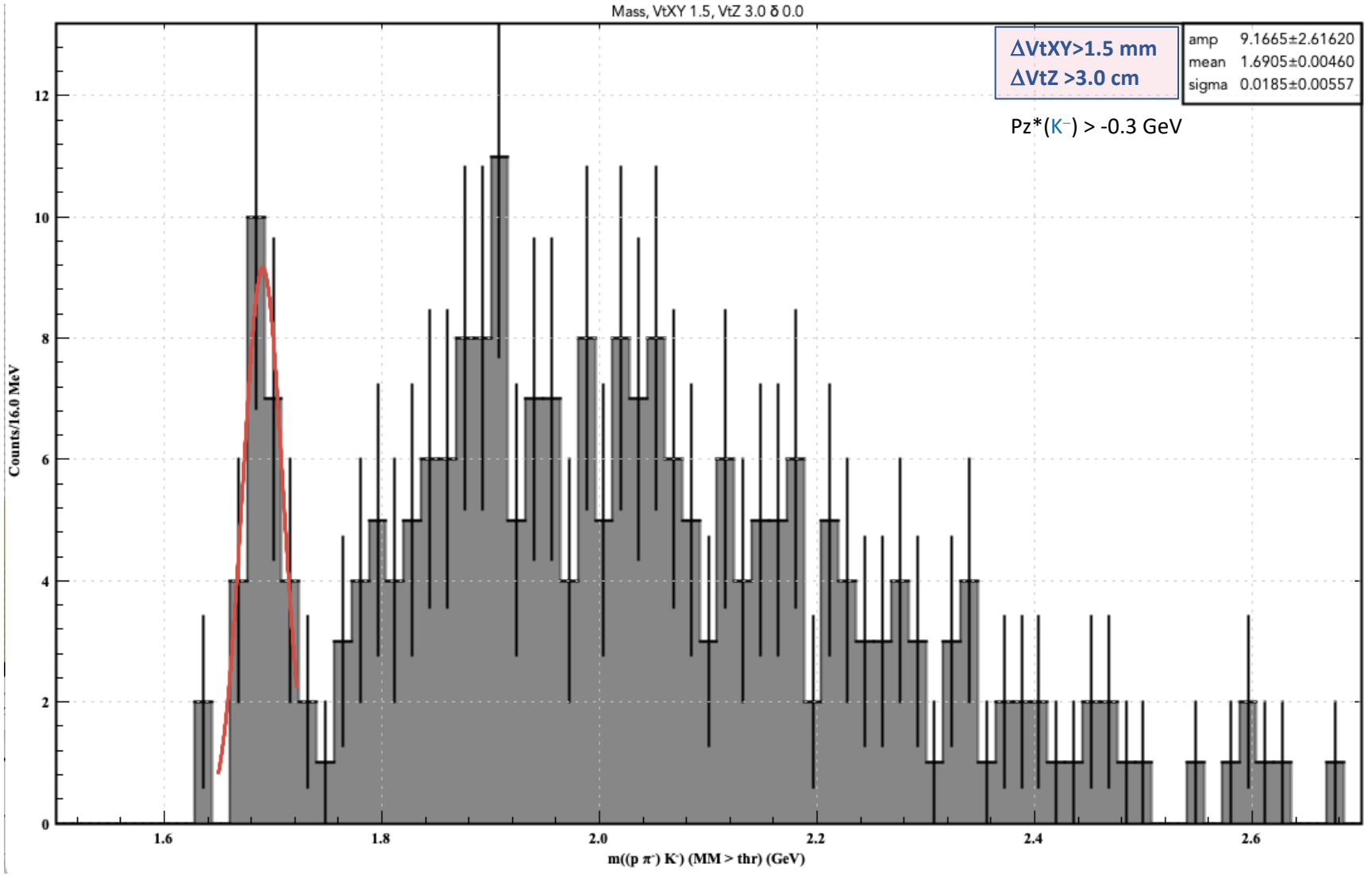
Possible ***evidence*** for a peak in m((p π^-) K^-) distribution consistent with the Ω^-

- With the currently available datasets, statistical significance ~3
- Momentum corrections needed
- MC samples to be produced to study backgrounds

REMARKS:

- W/o momentum correction
  - Λ mass peak shifted by about +5 MeV wrt PDG
  - m((p π^-) K^-) peak shifted by + 17 +/- 5 MeV wrt PDG Ω^- mass
    - no K^- vertex vertex correction
    - Effect of binning on peak position (next slide)
    - m((p π^-) K^-) spectrum has large bins (limited stats)

M = 1.6905 GeV



Effect of binning on the m((p π^-) K^-) distribution

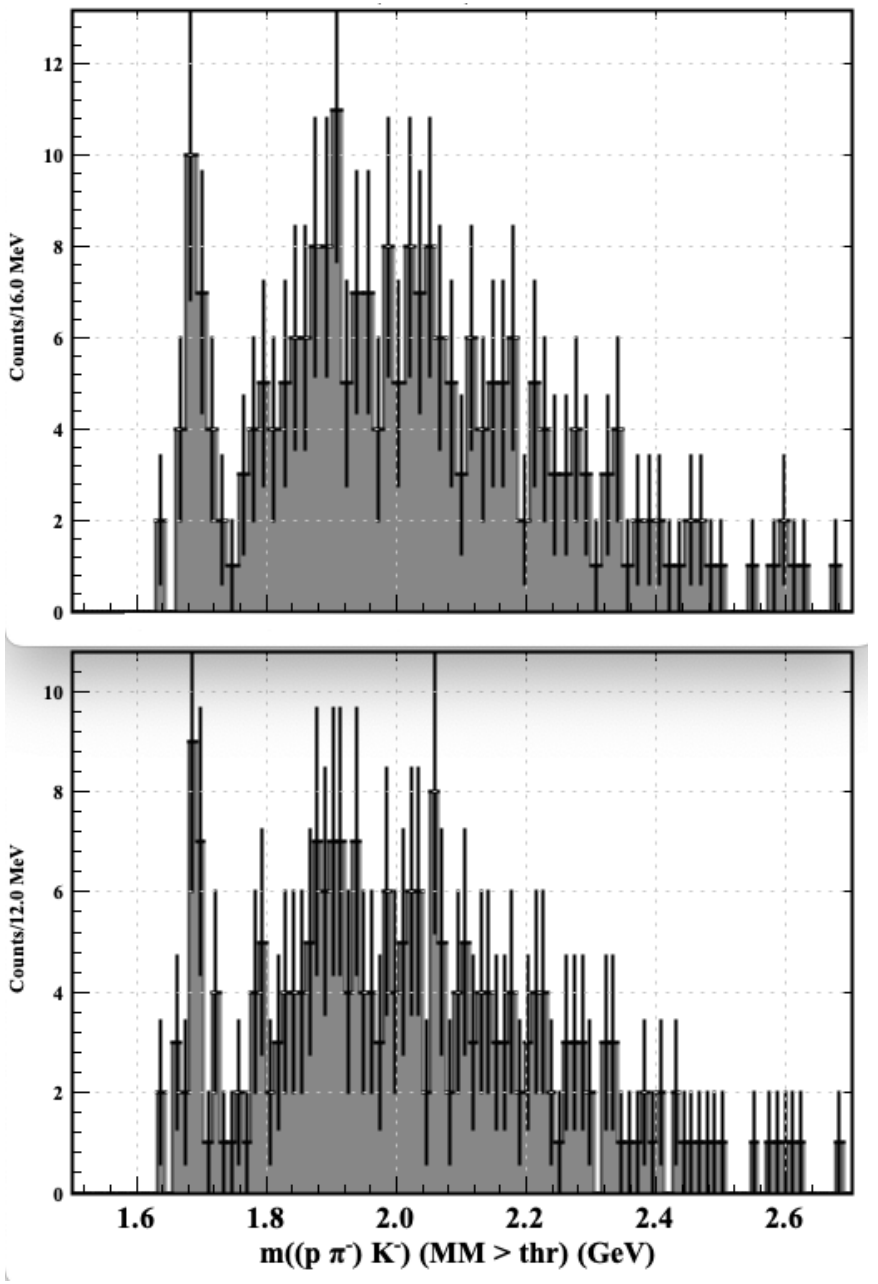
- Finer binning (12 MeV) plot exhibits a sharper drop on the right-hand side compared to the left-hand side of the peak.
  - May be indicative of higher inefficiency as a function of mass at lower mass. The efficiency correction distribution as a function of mass obtained from MC would show the efficiency dependence on reconstructed m(Λ K^-). If the inefficiency is not flat, so that it is higher in the lower mass bins than in the higher bins, this would move the fitted mass to the right of the spectrum.

- The finer binning gives a fitted peak position 5 MeV lower than the coarser binning plot.

ΔVtXY>1.5 mm
ΔVtZ >3.0 cm

16 MeV Bins

12 MeV Bins



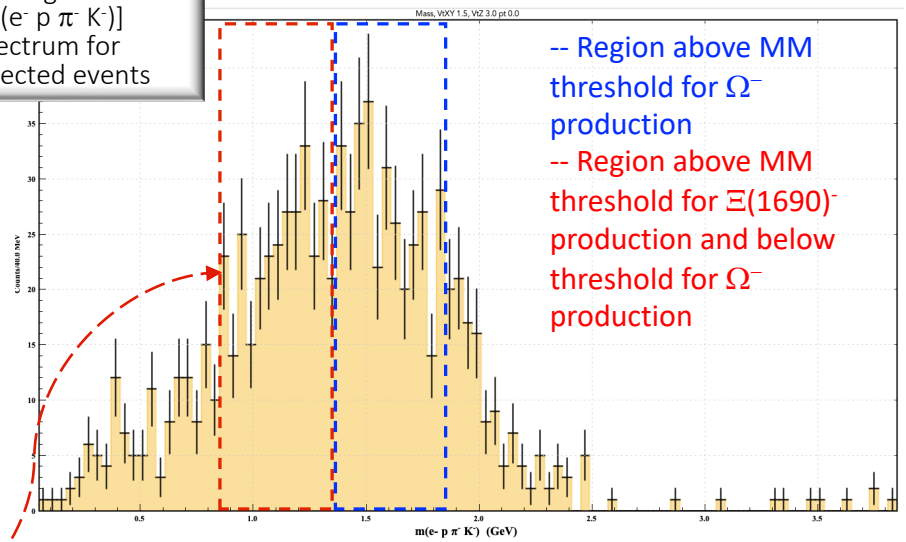
Potential Overlap with the $\Xi(1690)^- \rightarrow \Lambda K^-$

Looking for evidence for $\Xi(1690)^- \rightarrow \Lambda K^-$ production

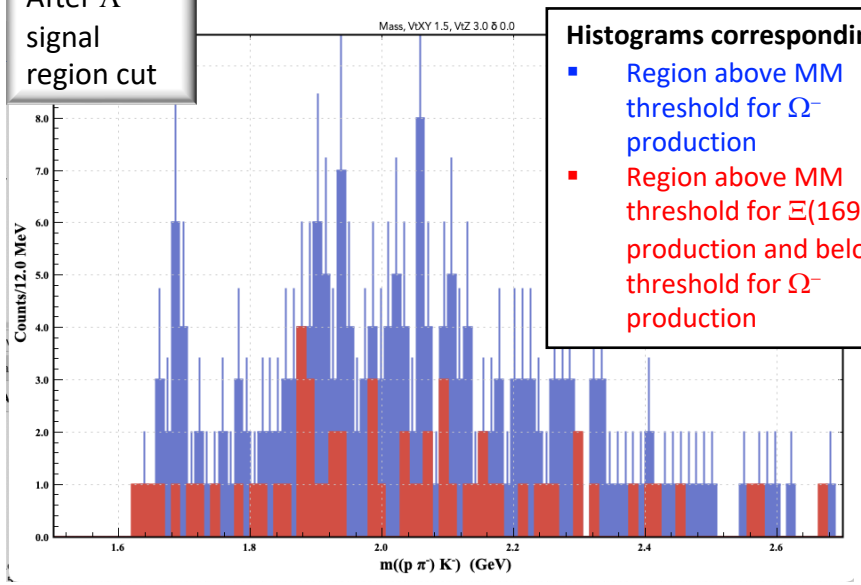
By Missing Mass [MM($e^- p \pi^- K^-$)] Analysis

- The Missing Mass (MM) threshold for $\Xi(1690)^-$ *[dss]* production correspond to the sum of the masses of 2 kaons. Taking into account resolution effect, the threshold is estimated to be 0.85 GeV
- We would expect some $\Xi(1690)^-$ production to occur for MM($e^- p \pi^- K^-$)] in the region above MM threshold for $\Xi(1690)^-$ production and below threshold for Ω^- production
- No peak is observed in the red distribution corresponding to this MM range

Missing Mass [m($e^- p \pi^- K^-$)] spectrum for selected events



After Λ signal region cut



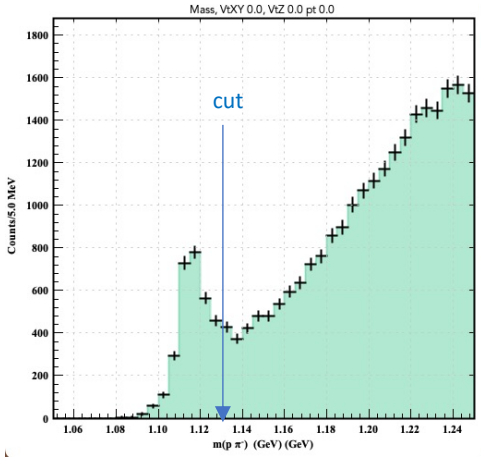
Potential Overlap with the $\Xi(1690)^- \rightarrow \Lambda K^-$

Looking for the $\Xi(1690)^-$ neutral partner

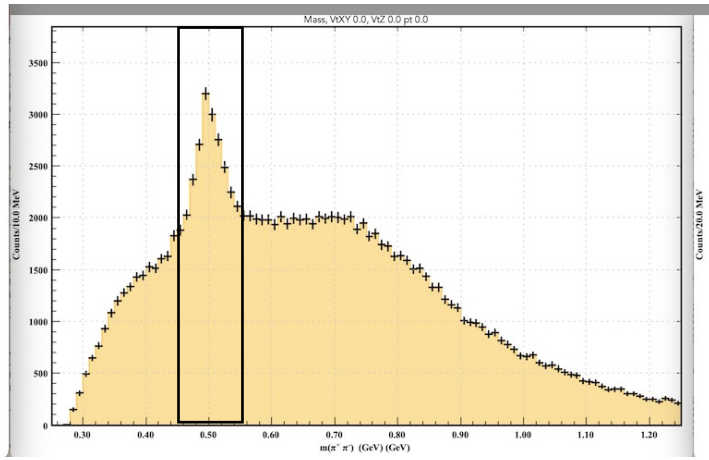
$\Xi(1690)^0 \rightarrow \Lambda \bar{K}^0$ ($\bar{K}^0 \rightarrow K_S$)

By direct search for a $\Xi(1690)^0$ signal

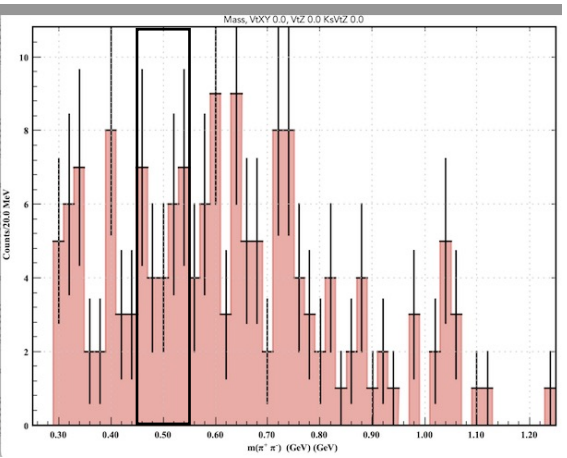
- **Reaction $e^-p \rightarrow e^- (\Lambda \bar{K}^0) K^+ X$**
  - X [not reconstructed] $=K^0 +\ldots$
- Require the proton in the FD, vertexing, Λ decay z vtx greater than K^+ vtx, K_S^0 decay z vtx greater than K^+ vtx
- For Λ signal region selection, no K_S^0 signal observed; without any selection cut on the $m(p\pi^-)$ spectrum a clear K_S^0 signal is observed
- **No correlation between the Λ signal and the K_S^0 after a missing mass cut corresponding to 2 kaon threshold**
- No evidence for $\Xi(1690)^0$ in ΛK_S^0 decay



$m(\pi^+\pi^-)$ before Λ signal region selection cut

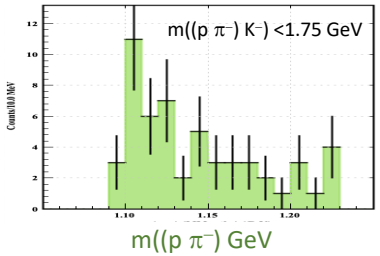


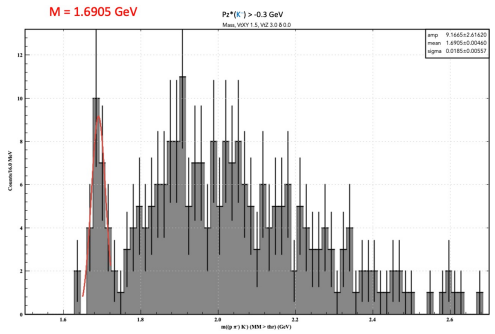
$m(\pi^+\pi^-)$ after Λ signal region selection cut and missing mass cut



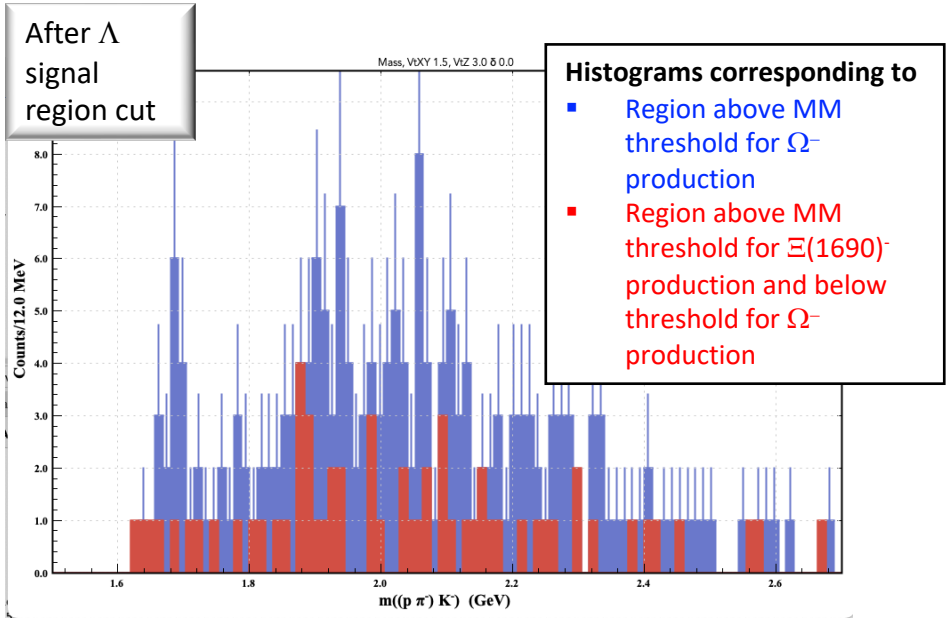
Summary of Observations

- Correlation between peak in m((p π^-) K^-) and Λ signal [for m((p π^-) K^-) <1.75 GeV]





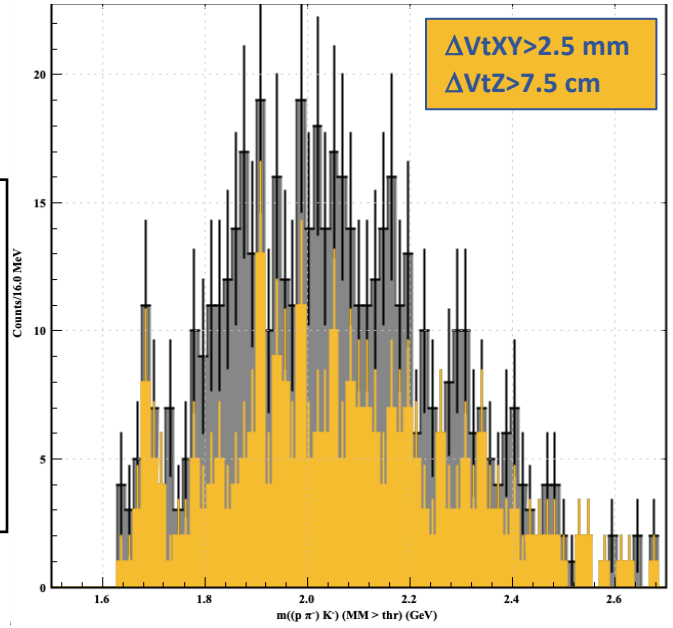
- No obvious contribution from the $\Xi(1690)^-$



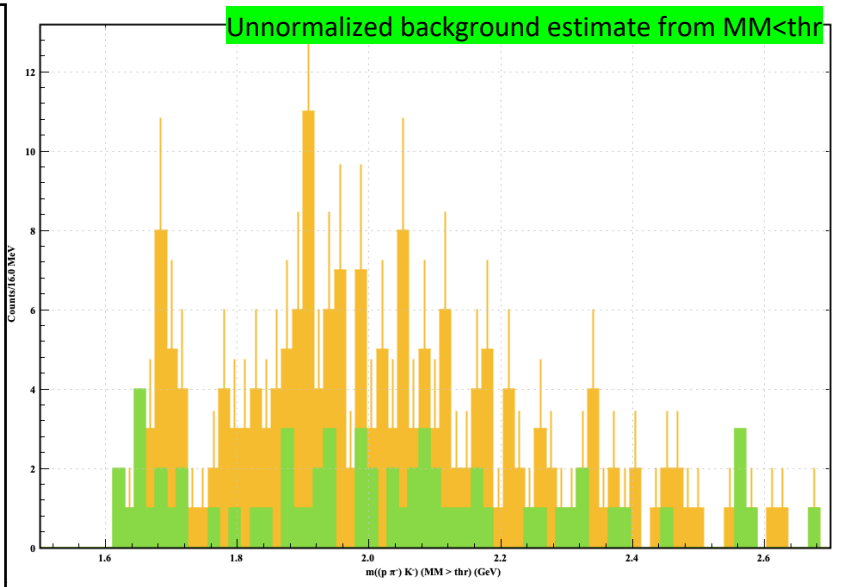
- Vertex displacement cuts aimed at reducing hyperon background while retaining signal do not produce significant reduction is observed threshold peak in m((p π^-) K^-)

Loosest vtx displacement cuts
Tighter vtx displacement cuts

- Behavior consistent with signal
  - ✓ minimal reduction in yield with increasing vertex displacement cuts



- Clear observation of signal over background in the inv. mass region corresponding to the Ω^- mass
- Possible evidence for Ω^- signal
- Also seen when dividing the datasets (in/out-bending, e- in FT/EC)

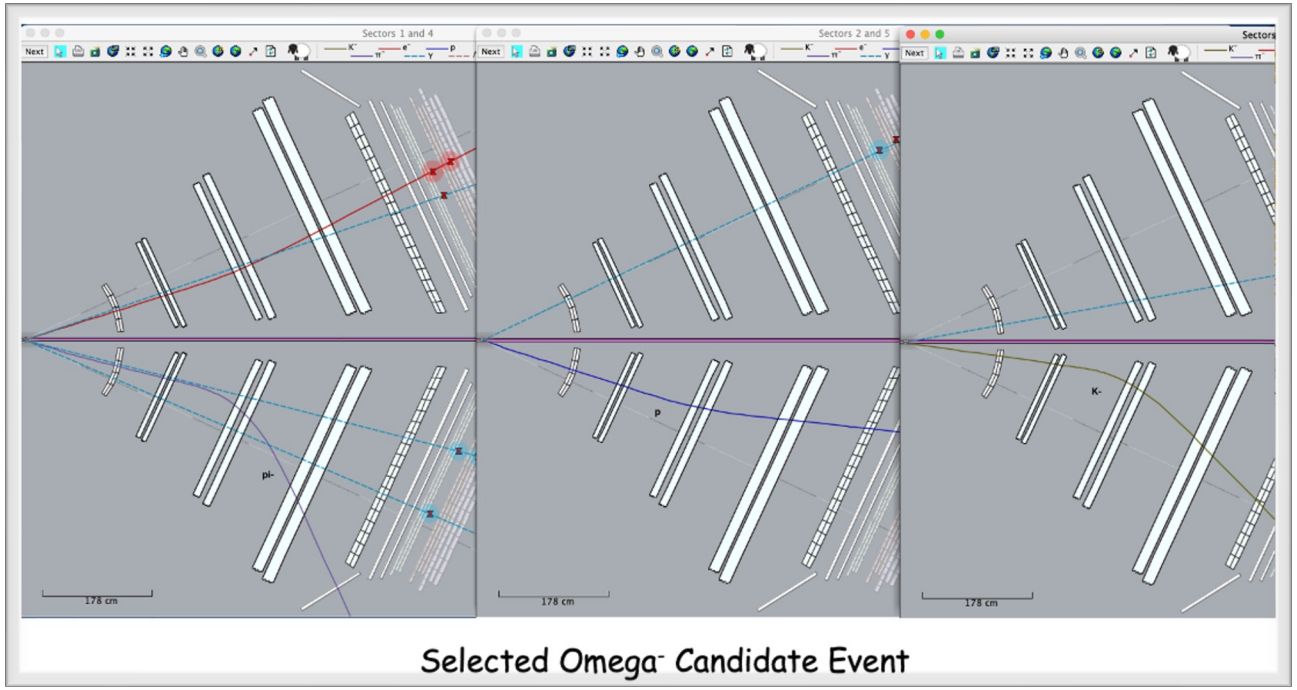


Next Plans

- Momentum corrections
- MC samples generation
  - $e^- p \rightarrow e^- \Omega^- K^+ K^+ K^0$
    $\Omega^- \rightarrow \Lambda K^-$
    $\Lambda \rightarrow p \pi^-$
  - $e^- p \rightarrow e^- \Lambda K^+$
    $\Lambda \rightarrow p \pi^-$
  - $e^- p \rightarrow e^- \Lambda K^+ \pi^+ \pi^-$
    $\Lambda \rightarrow p \pi^-$
  - $e^- p \rightarrow e^- p \pi^- K^- K^+ \pi^+$

→ Bg studies

- Background events analysis → Investigate ML techniques
  - misID (anti-p for K-)
  - Simulate Xi(1690)
  - Mixed events: K- from different events
- Check topology of Omega candidates
- Analysis note



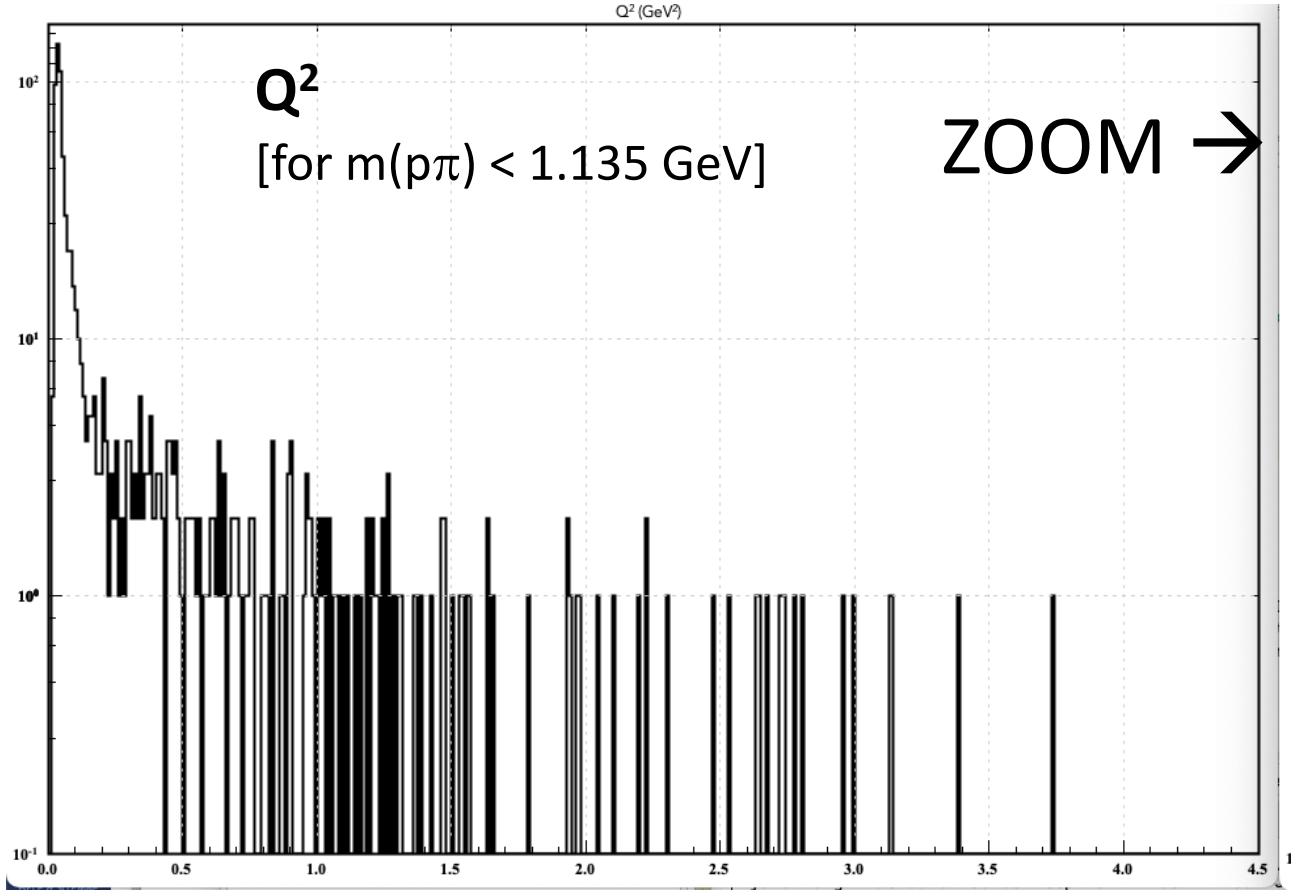
Selected Omega⁻ Candidate Event

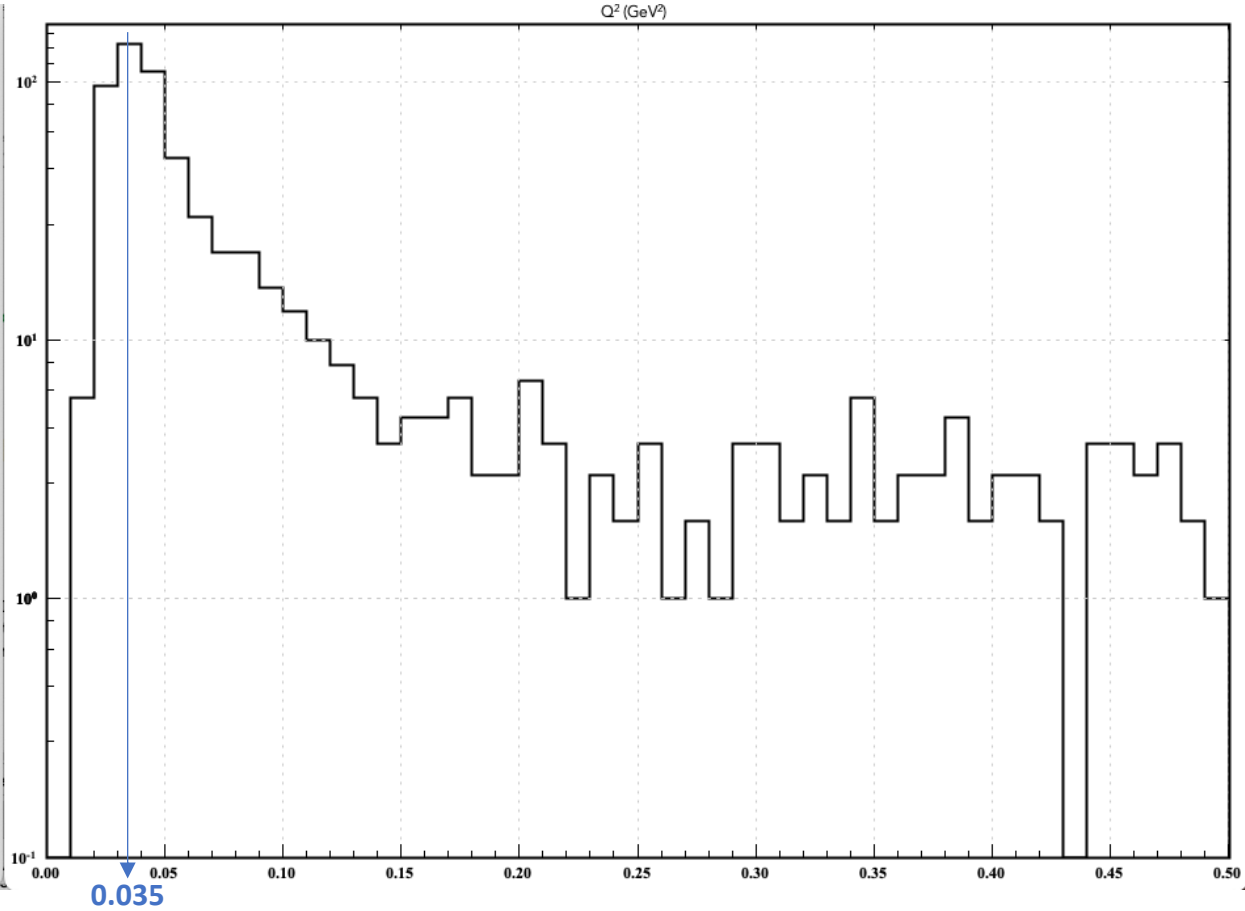
BACK-UP SLIDES

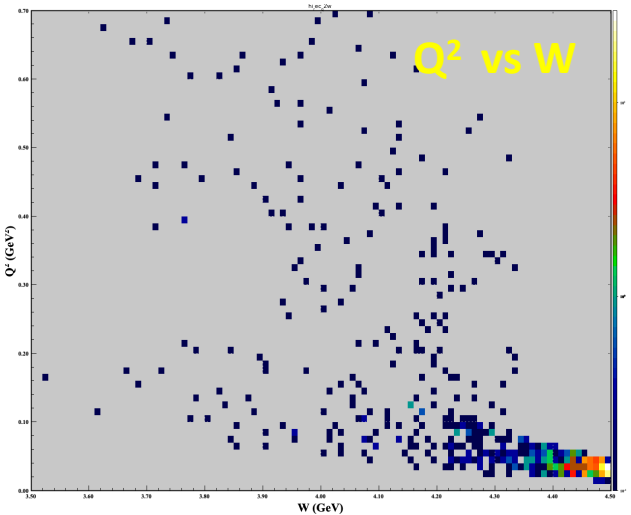
Q^2

[for m(pπ) < 1.135 GeV]

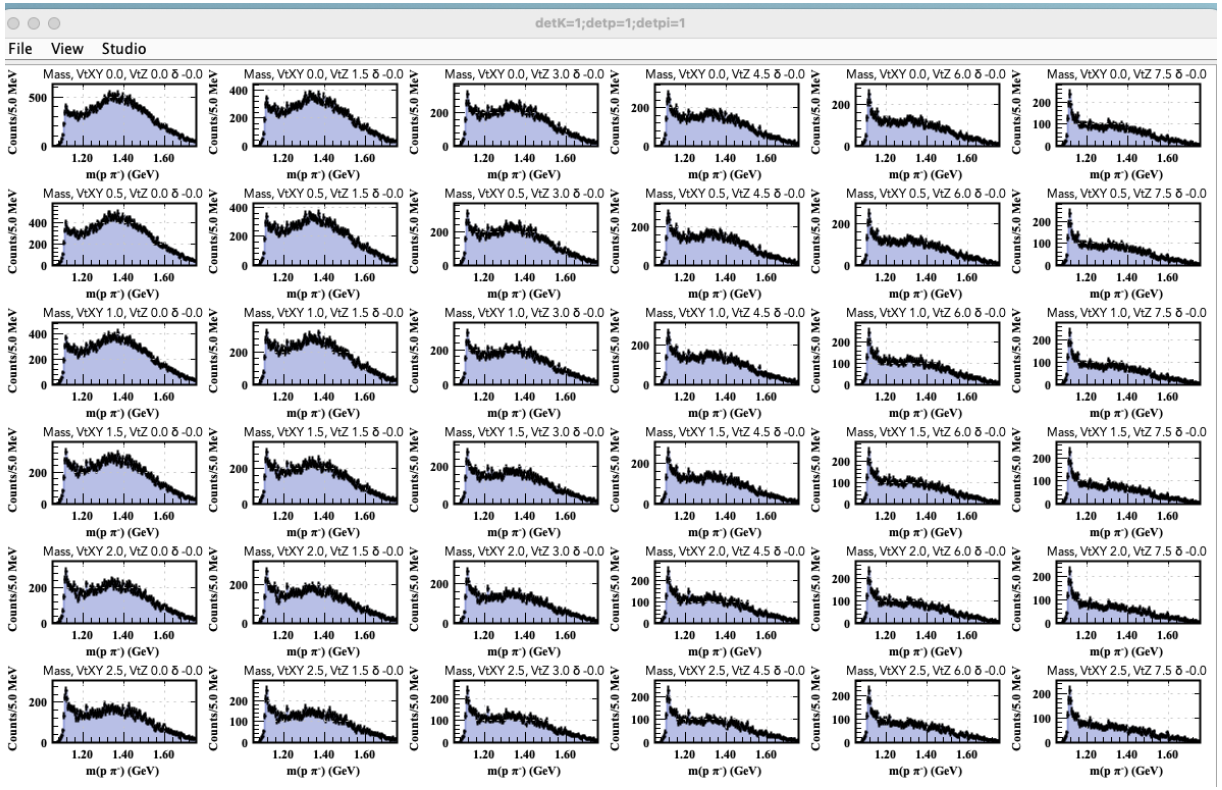
ZOOM →

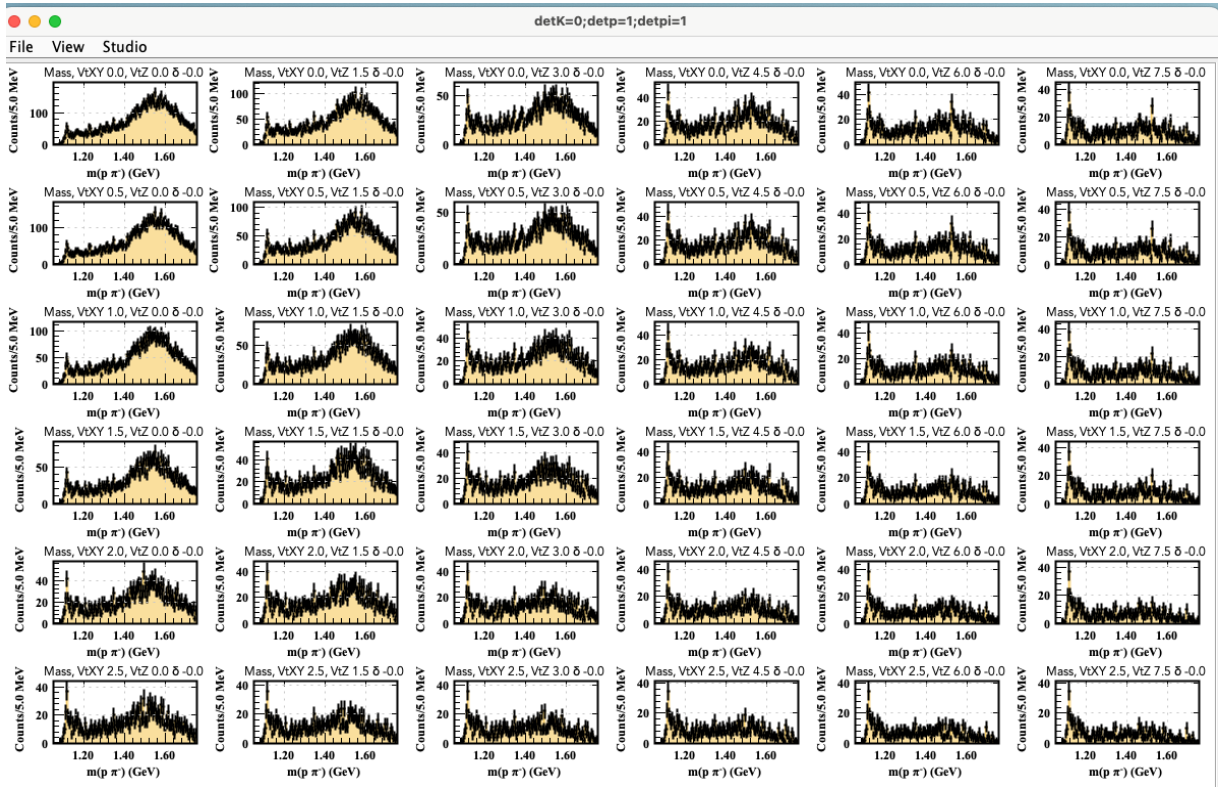




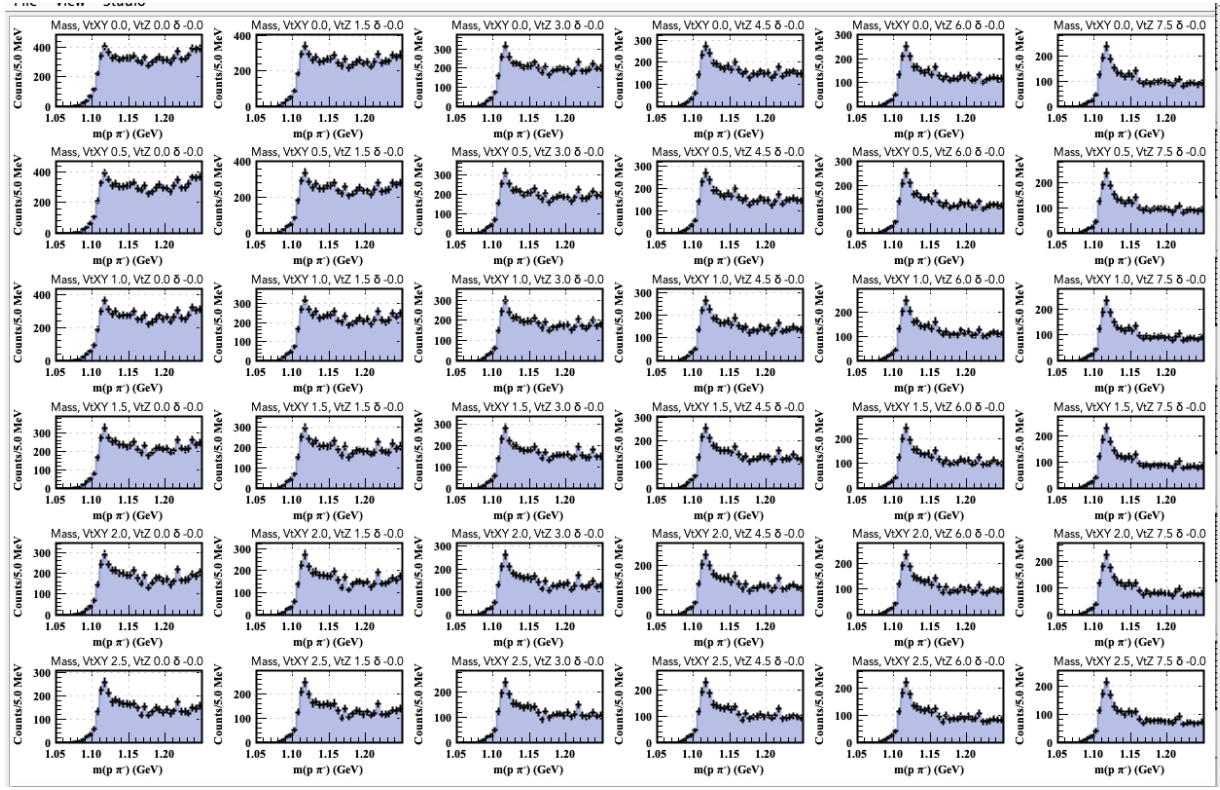


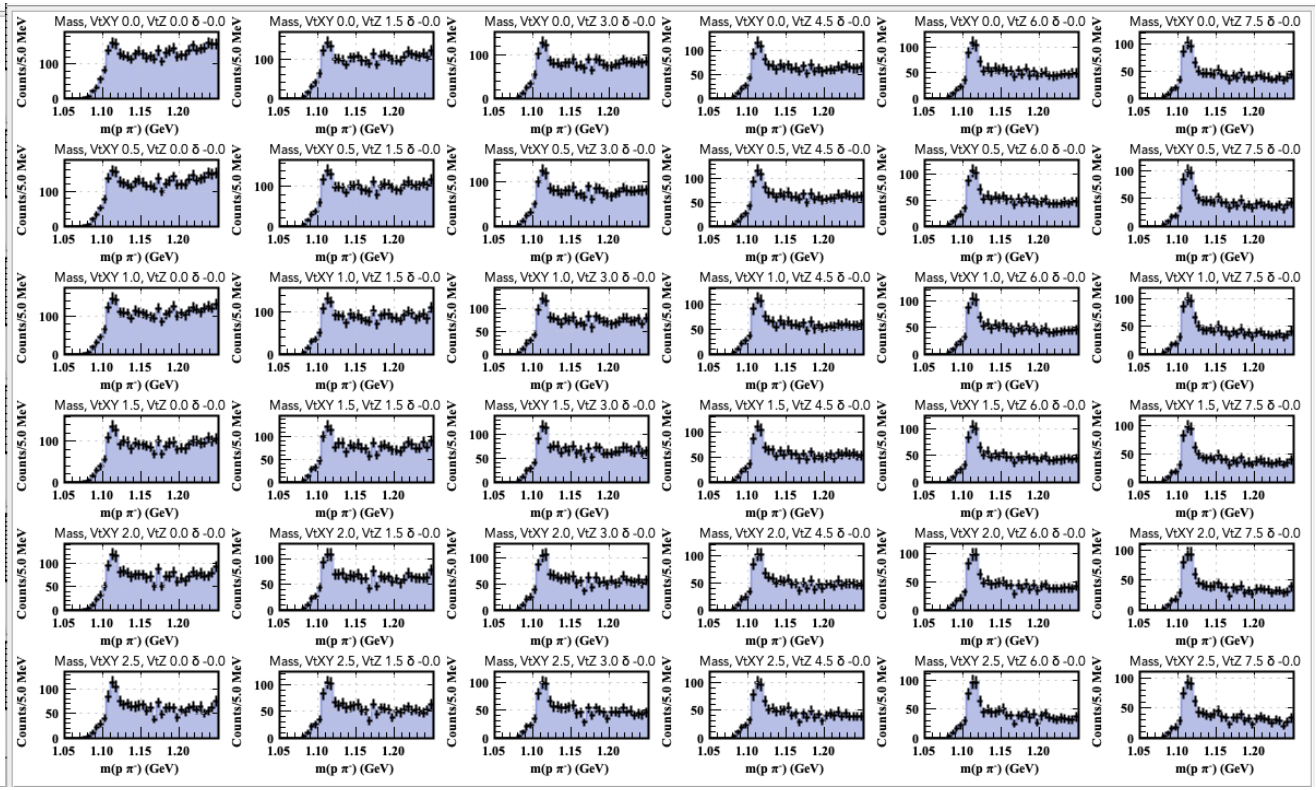
Cuts: |c2pid|<15, pt(p)>500 MeV,MM>1.35 GeV,



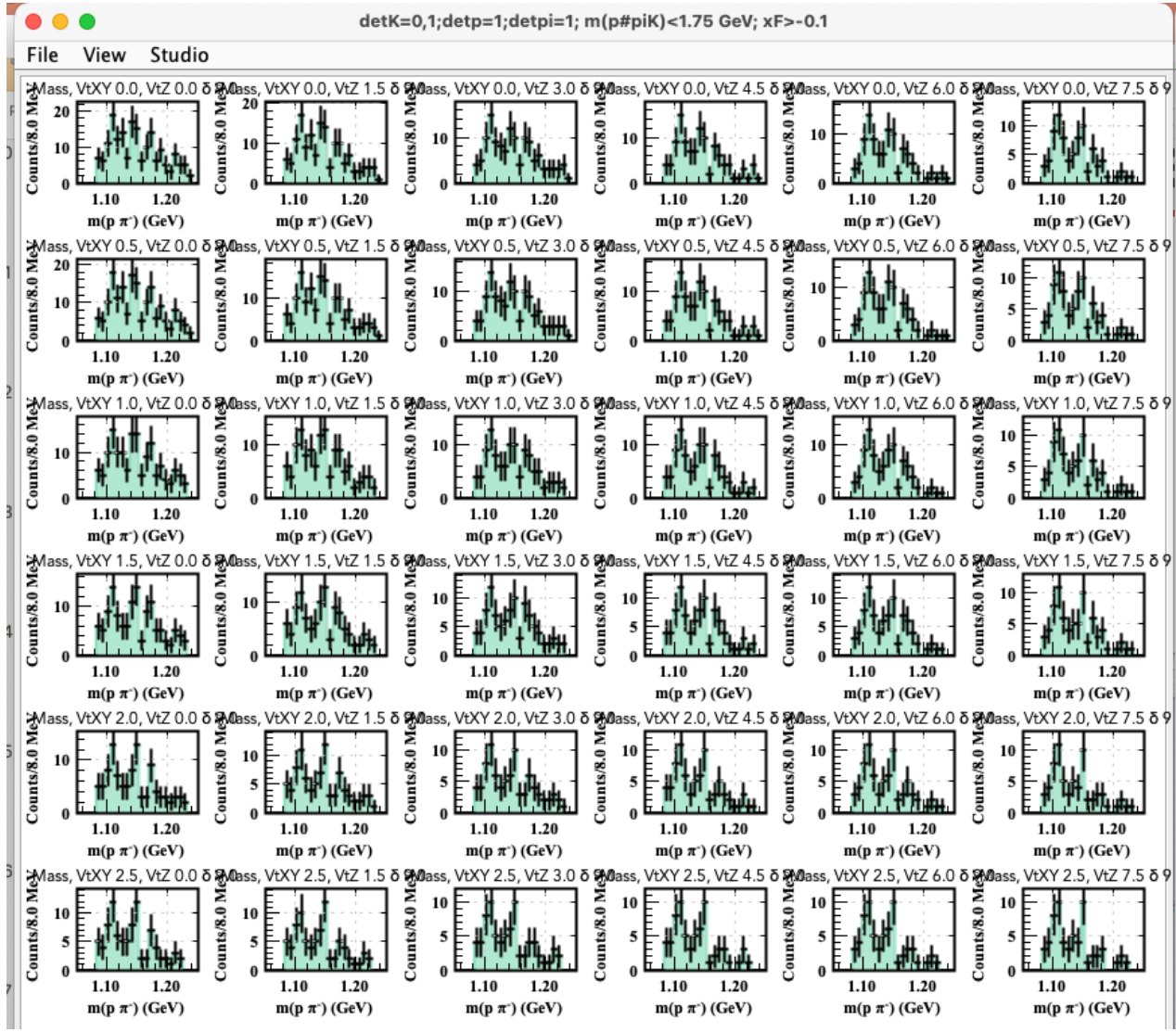


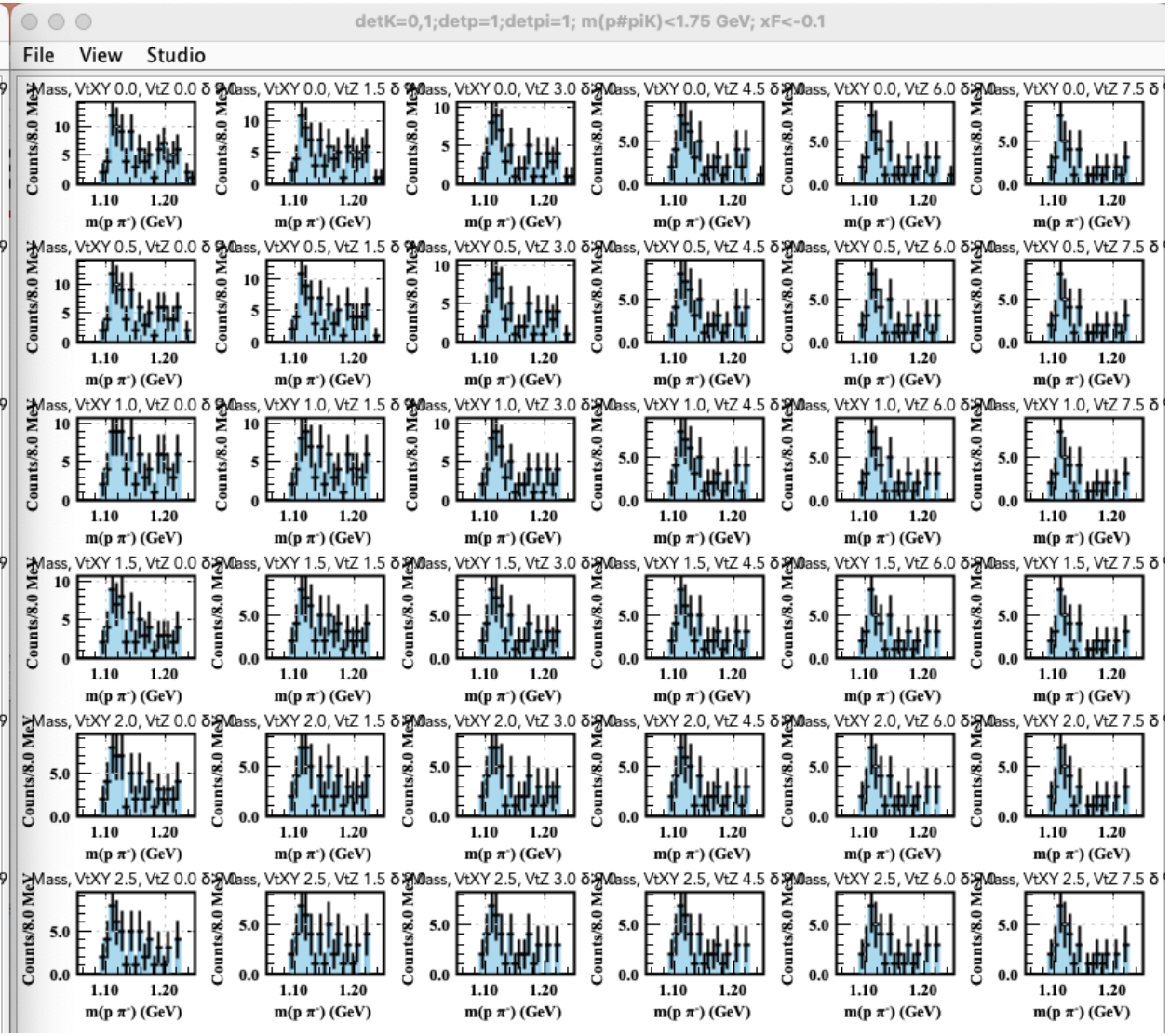
w/out and w/ angle cut





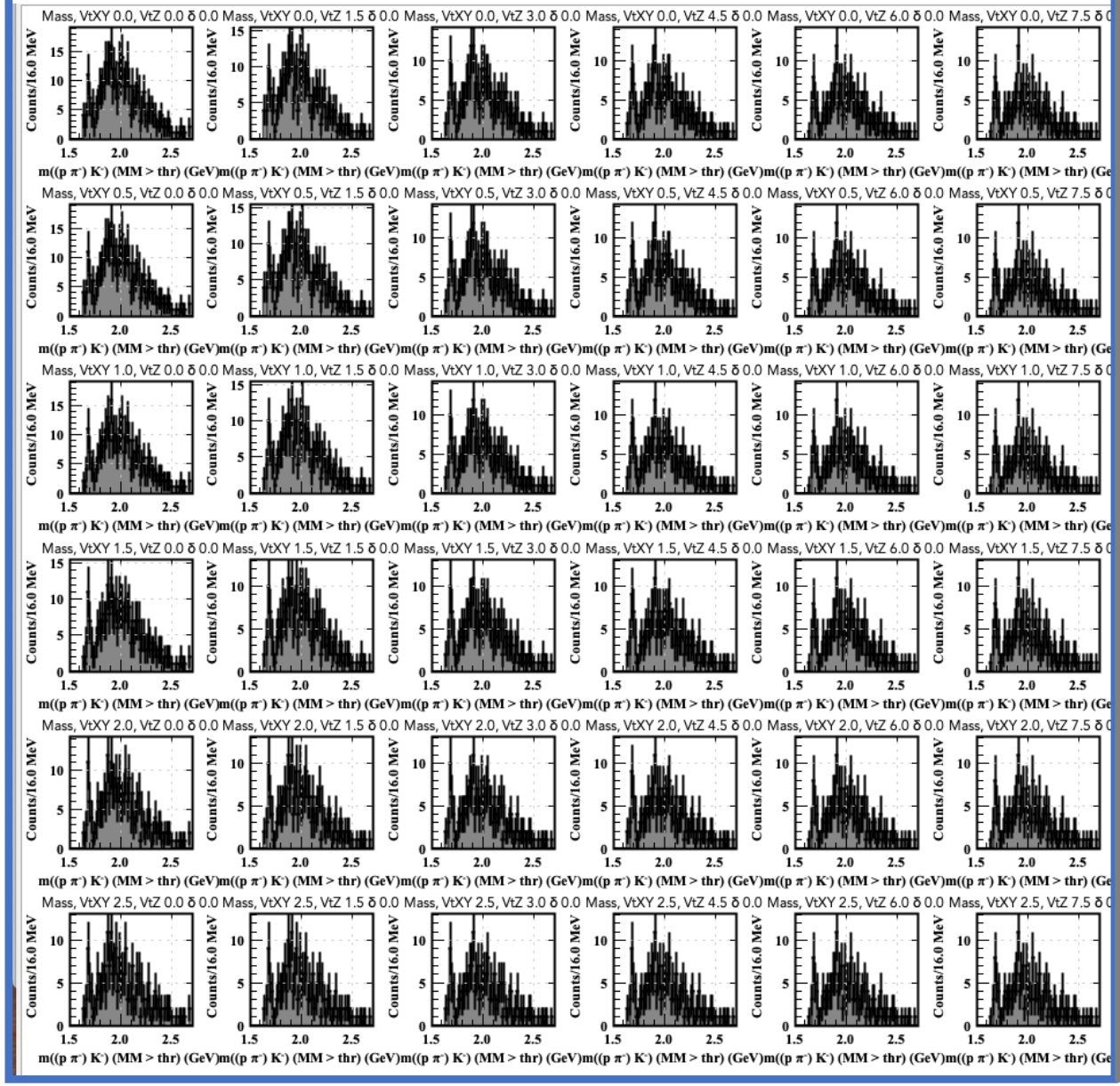
Lambda spectrum corresponding to expected Omega signal mass window in Regions xF > or xF < -0.1



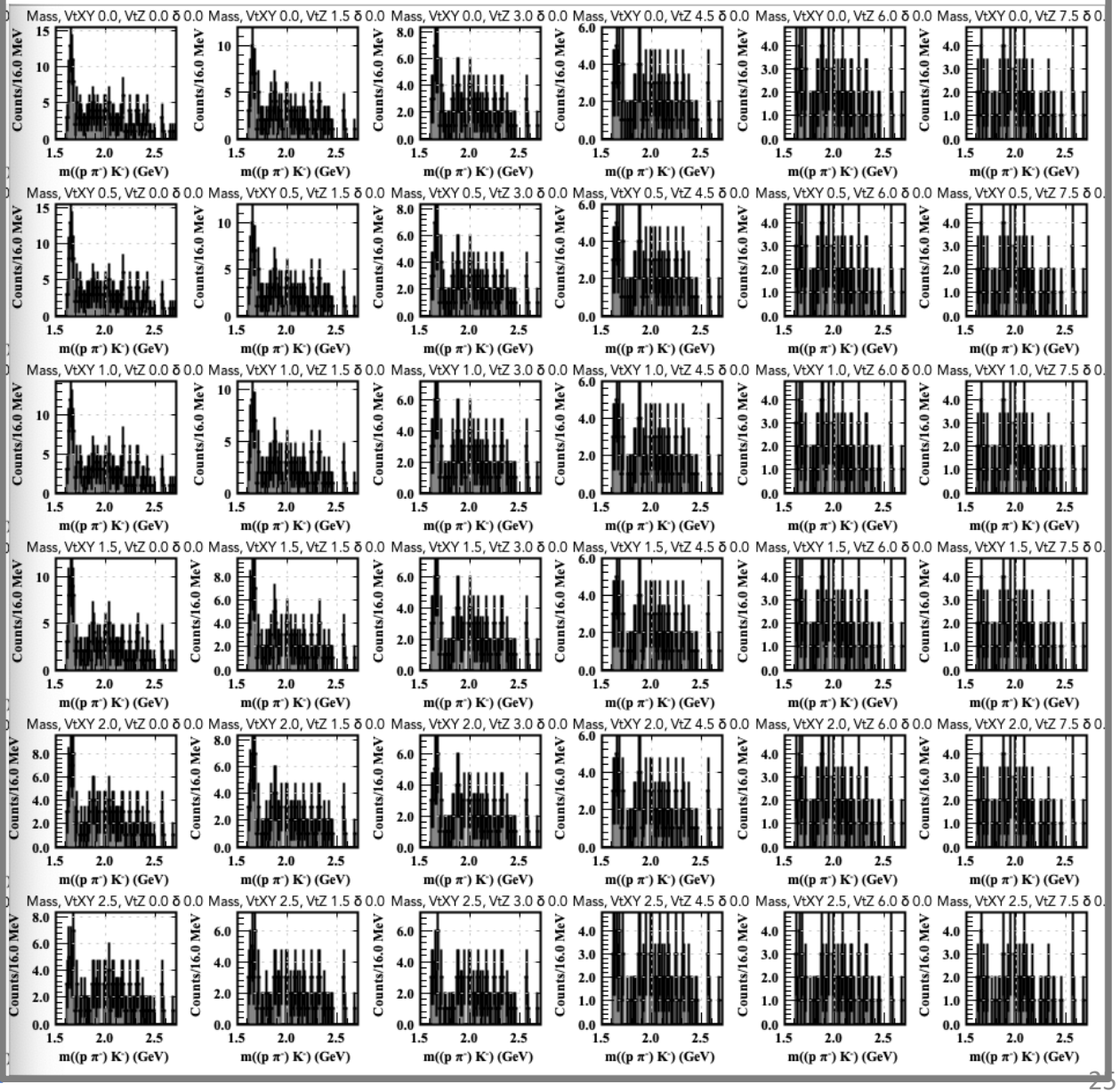


Pz*(K^-) > -0.3 GeV (π^- in FD; p in FD; K^- in CD or FD)

MM > 1..35 GeV



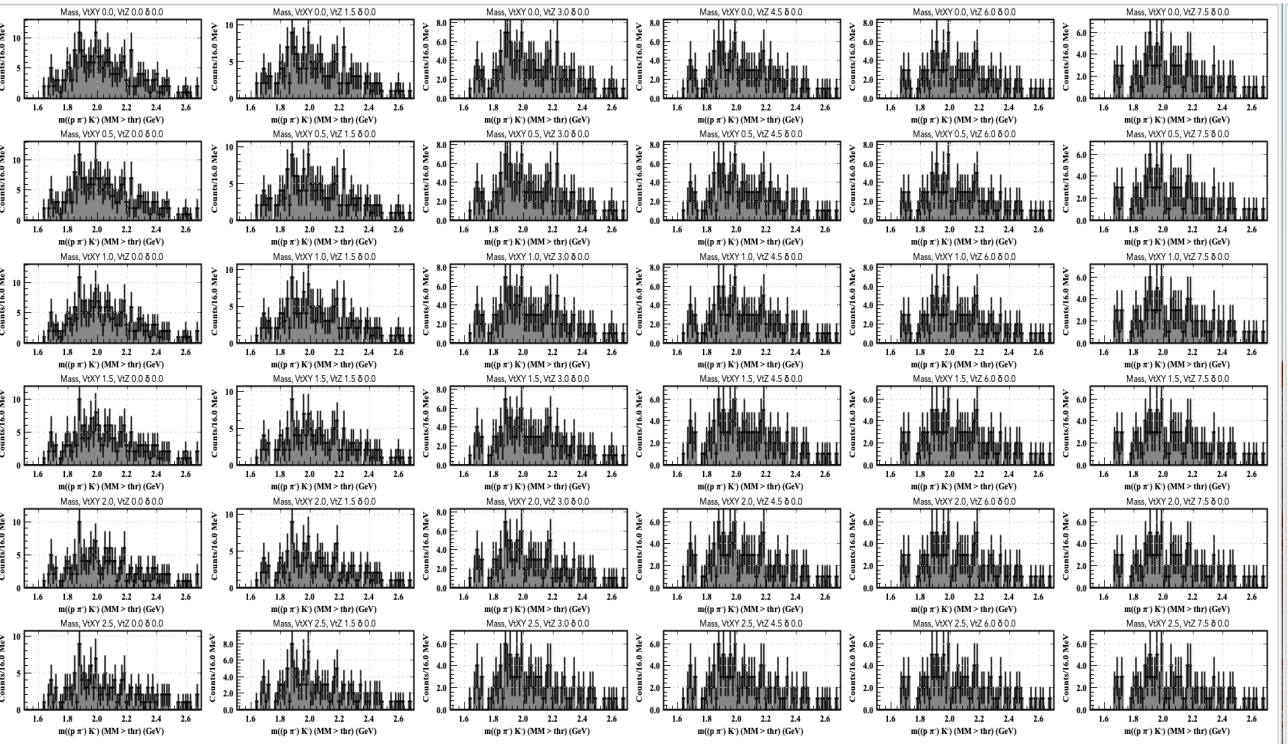
MM < 1.35 GeV



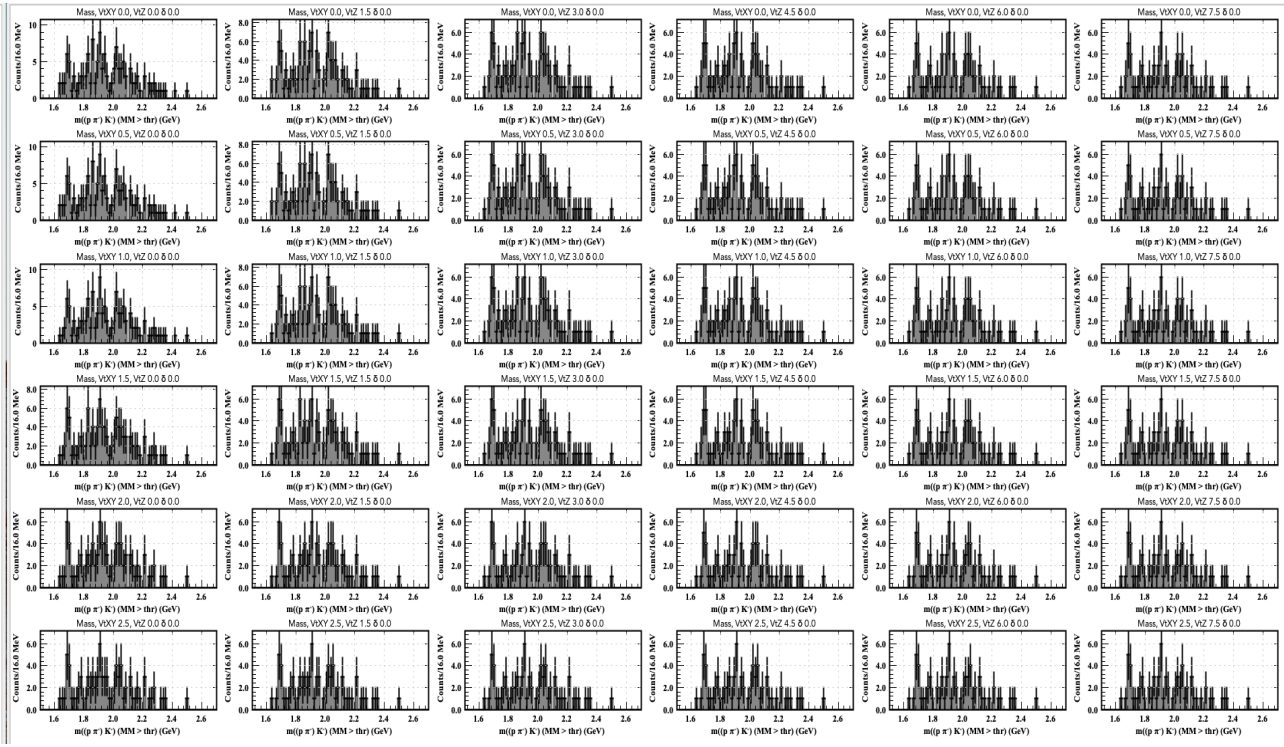
RGA
(e-in EC, FT)

With Pz*(K^-) > -0.3 GeV cut (π^- in FD; p in FD; K^- in CD or FD)

e-in FT



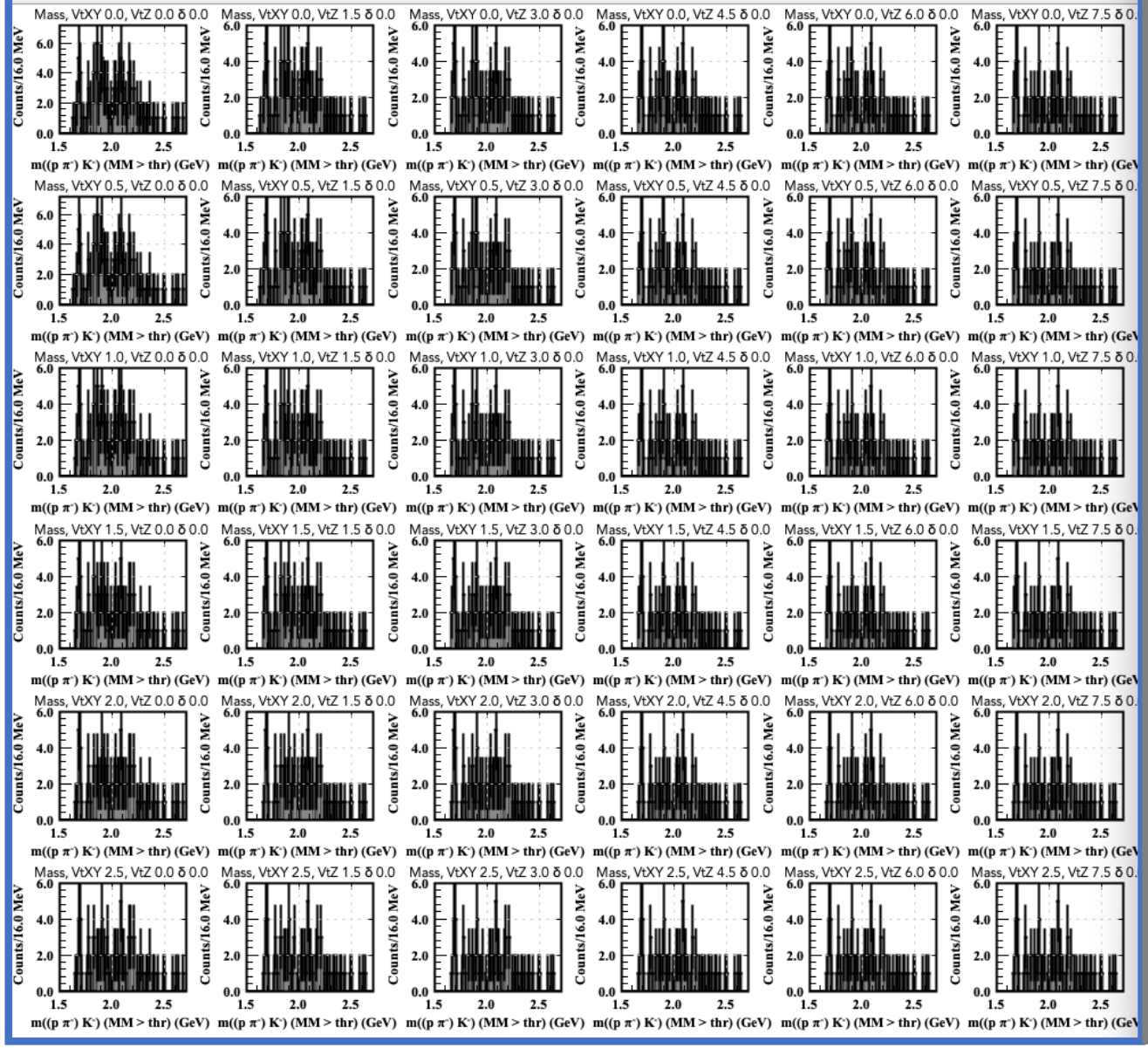
e-in EC



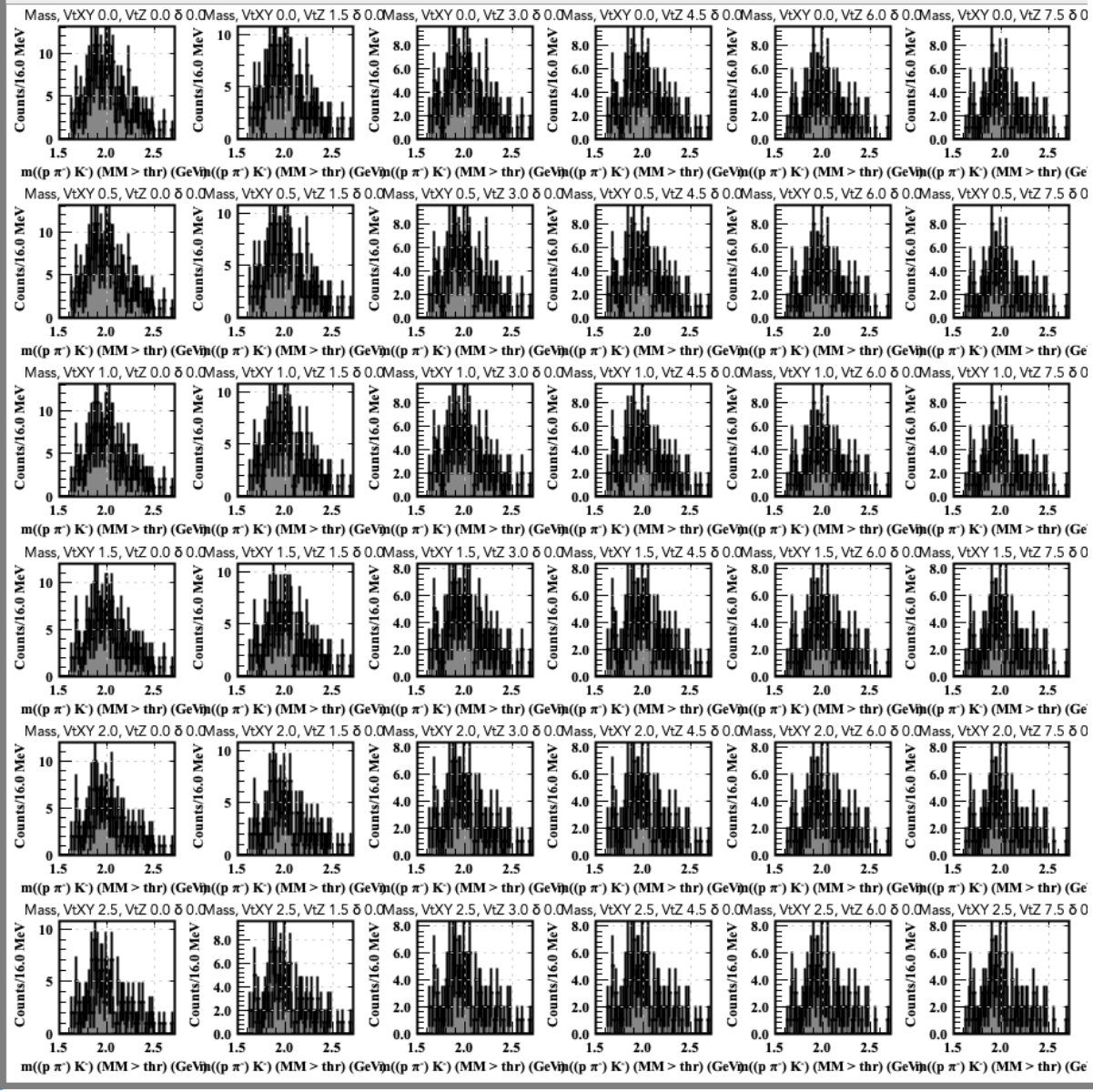
RGA
(e-in EC, FT)

With Pz*(K^-) > -0.3 GeV cut (π^- in FD; p in FD; K^- in CD or FD)

Inbending dataset



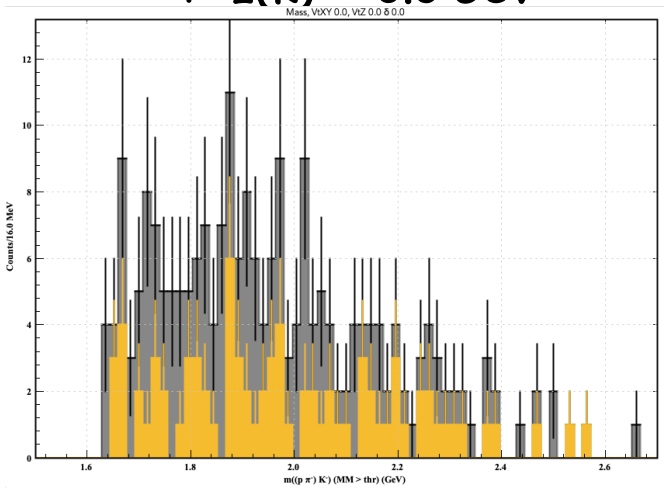
Outbending dataset



Observations (MM > thr; thr=1.35 GeV (RGA); =2.35 GeV (RGB))

RGB (e-in EC)

P*z(K) > -0.3 GeV



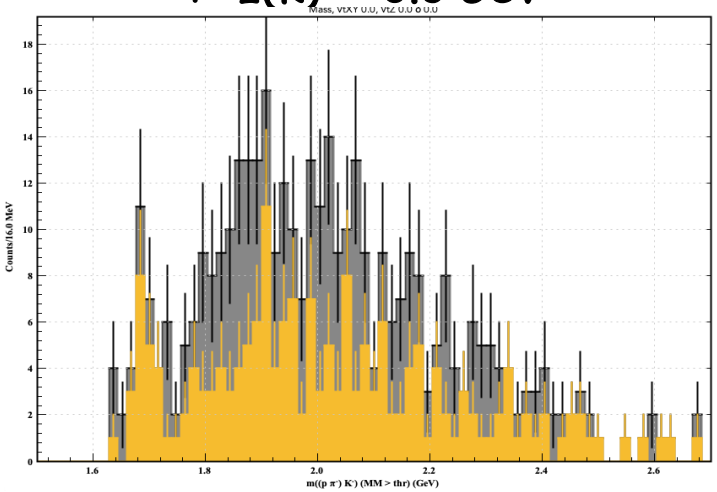
Loosest vtx displacement cuts

Tightest vtx displacement cuts

- Behavior consistent with bg further evidenced by P*z(K) cut

RGA (e-in EC, FT)

P*z(K) > -0.3 GeV



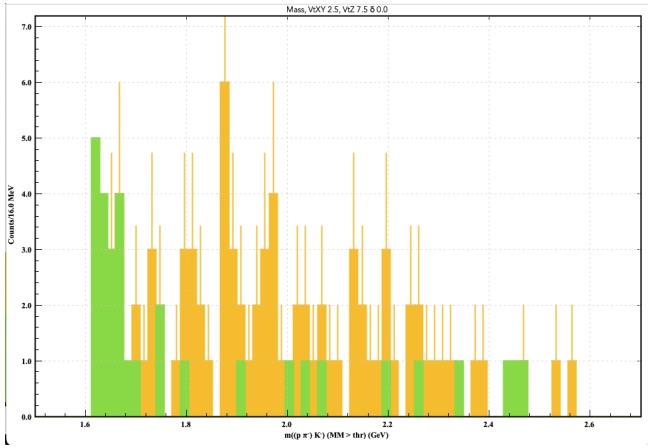
Loosest vtx displacement cuts

Tightest vtx displacement cuts

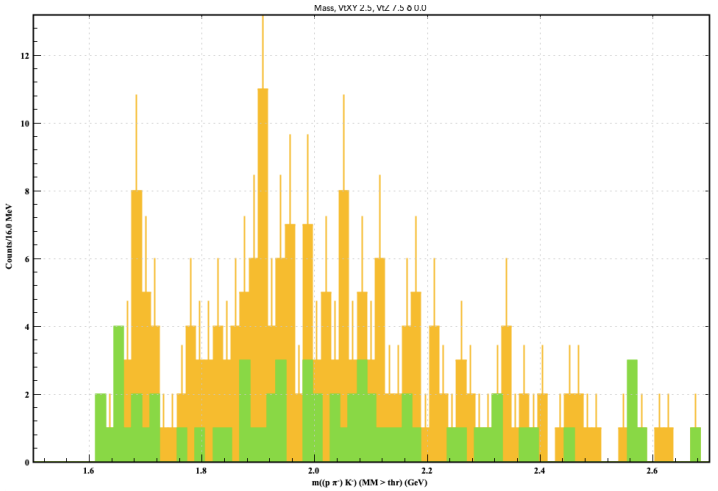
- Behavior consistent with signal further evidenced by P*z(K) cut

Unnormalized background estimate from MM<thr

- Enhancement at invariant mass spectrum threshold consistent with bg
- No evidence for Ω– signal



- Clear observation of signal over background in the inv. mass region corresponding to the Ω– mass
- Possible evidence for Ω– signal



- Production of the deuteron suppressed?
- Higher tracking background → lower efficiency than for RGA?

mm(e- p π^- K^-) vs m((p π^-) K^-) (π^- in FD; p in FD; K^- in CD or FD)

VtXY>1.5 cm; VtZ>3.0 cm