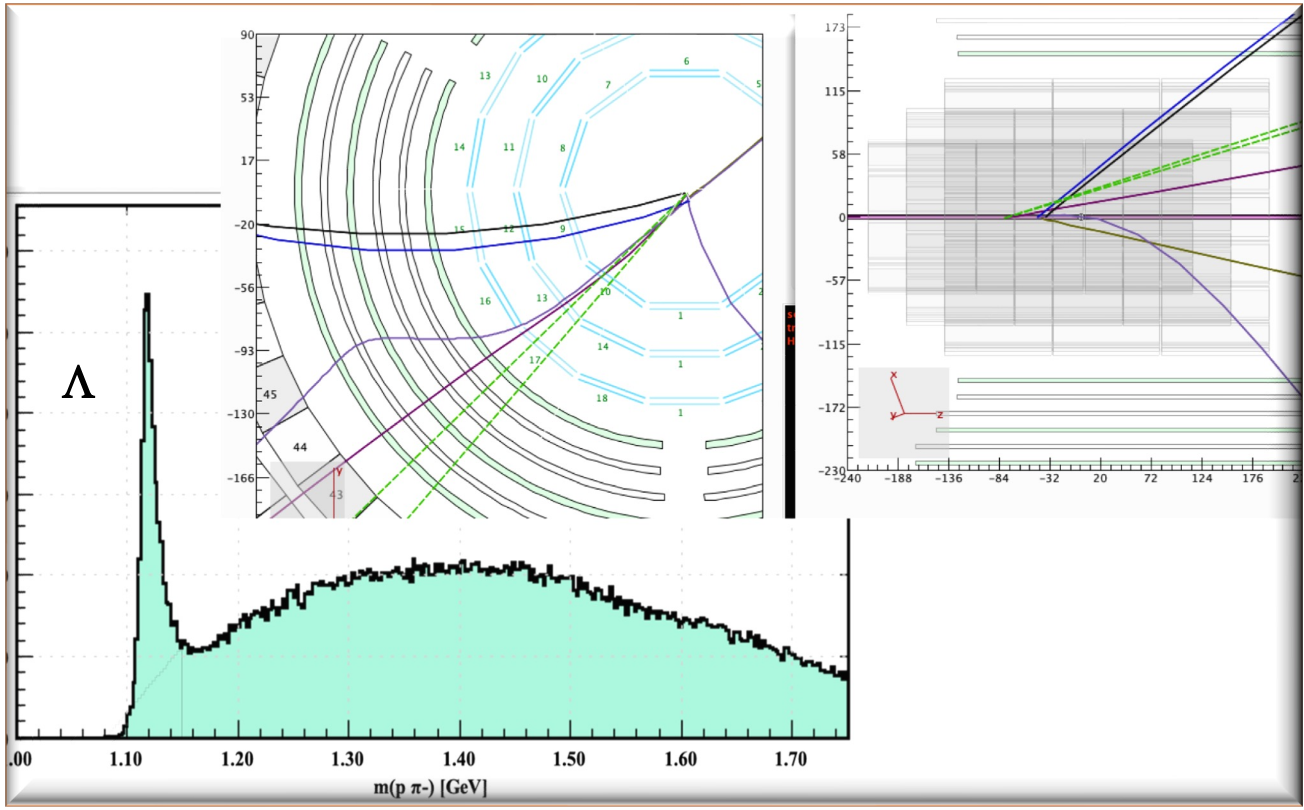
CLAS12 Collaboration Meeting

November 9, 2023

Detached Vertex Reconstruction

Veronique Ziegler

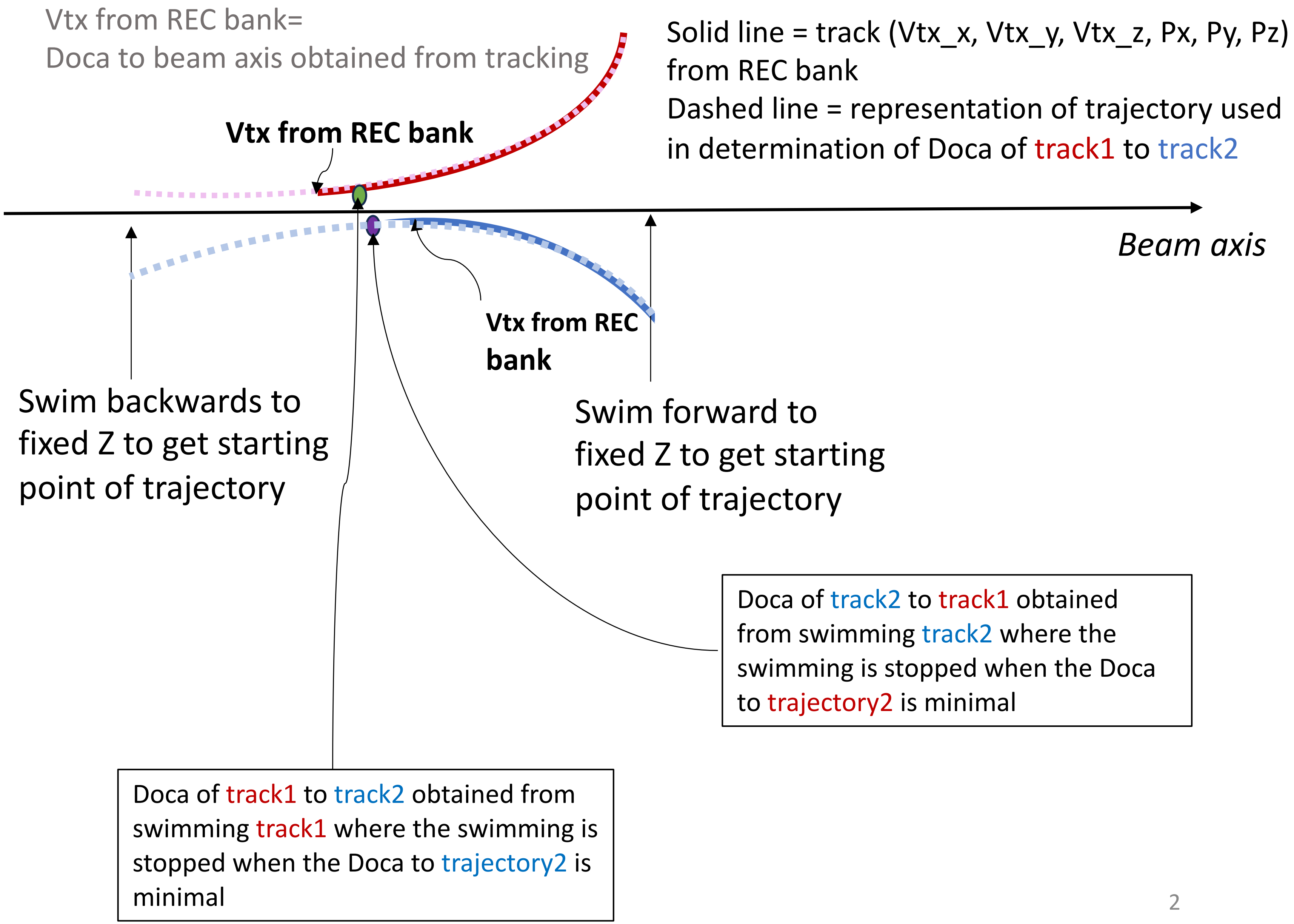


Detached Vertex Finder Algorithm

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

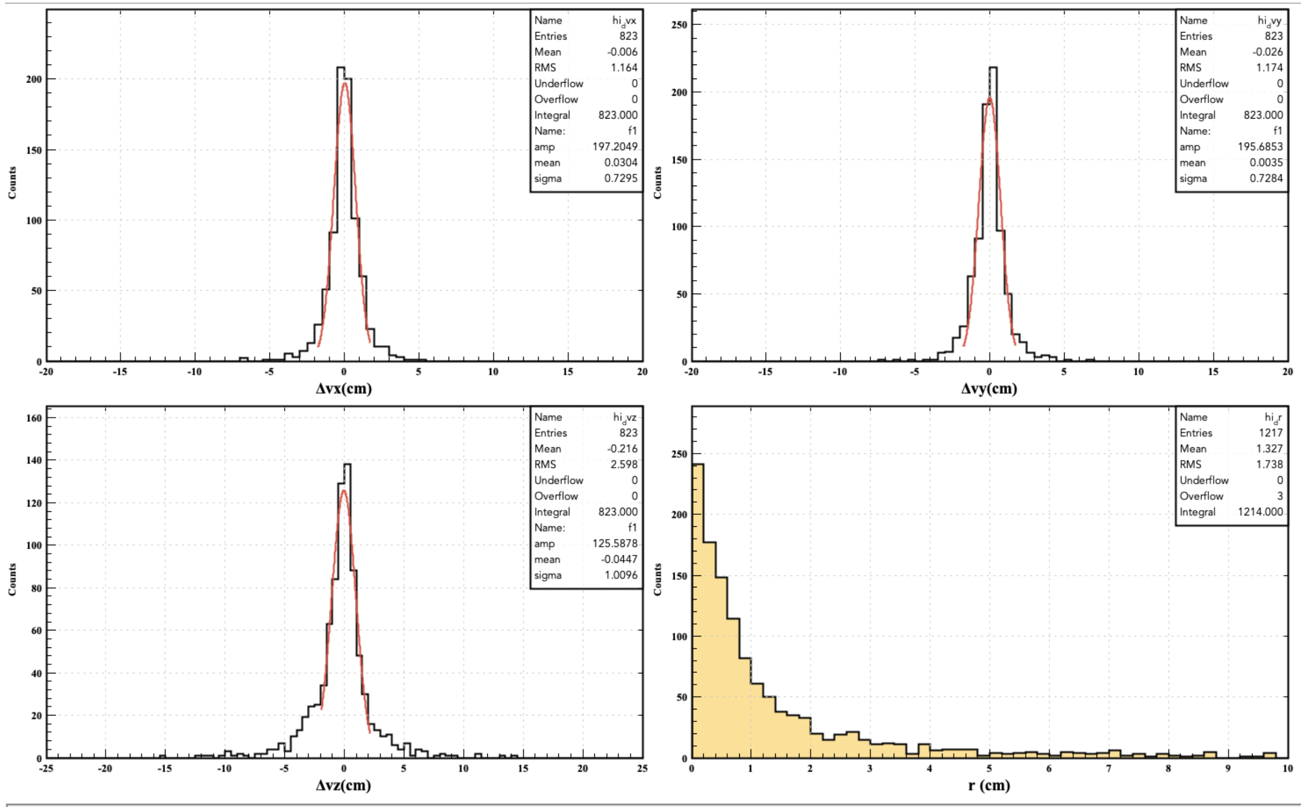


MC Vertex Resolution with Detached Vertex Finder

K Lambda MC + 35 nA Bg Validation

- Distributions centered
- Resolutions ~7 mm in xy, 1 cm in z are reasonable

Resolution (r<1.5 cm)



Banks Structures: Storing Decay Chains Info

REC::VertDoca

next prev seq # 5 true # 61971

	index1	index2	x	y	z	x1	y1	z1	cx1	cy1	cz1	x2	y2	z2	cx2	cy2	cz2	r
1	0	3	0.23567	0.19718	-4.84147	0.02829	-0.12346	-4.88774	-1.06517	1.08930	6.48670	0.44304	0.51783	-4.79521	0.77950	-0.37302	1.64688	0.76931
2	1	3	-0.44799	0.44935	-5.99327	-0.83723	0.13774	-6.12868	0.44936	-0.26925	0.66935	-0.05876	0.76095	-5.85787	0.77585	-0.38055	1.64688	1.03332
3	2	3	-2.08079	-0.51498	-8.20317	-3.00314	-2.34494	-8.20176	0.42425	-0.20998	0.64193	-1.15843	1.31497	-8.20457	0.76755	-0.39703	1.64688	4.09853

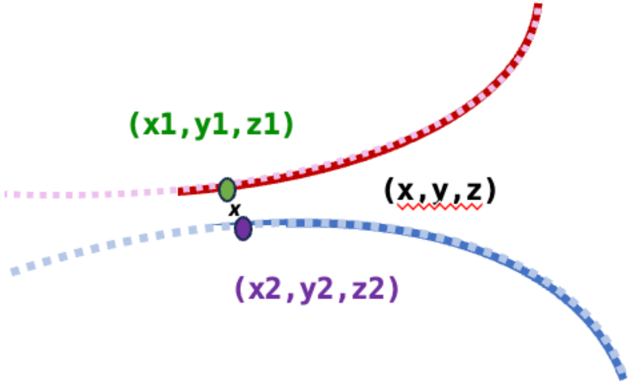
REC::Particle

next prev seq # 5 true # 61971

	pid	px	py	pz	vx	vy	vz	charge	beta	chi2pid	status
1	11	-1.06468	1.08978	6.48670	-0.00368	-0.09075	-4.69303	-1	1.00000	0.22344	-2232
2	-321	0.44785	-0.28637	0.67867	-0.15772	-0.22882	-5.13944	-1	0.90090	-0.95951	4100
3	-211	0.41435	-0.22890	0.64194	-1.74117	-3.00539	-6.27005	-1	0.98306	0.57529	2230
4	2212	0.77799	-0.37616	1.64688	0.23367	0.61854	-5.23798	1	0.88327	2.43717	2200
5	22	-0.13455	-0.33449	1.09944	-0.00368	-0.09075	-4.69303	0	1.01277	9999.00000	2020
6	22	0.07992	-0.01862	0.12999	-0.00368	-0.09075	-4.69303	0	0.91234	9999.00000	2010

REC::VertDoca = bank where doca information is stored

- Position x,y,z of reco displaced vtx
- 2-tracks momenta: cxi, cyi, czi
- r : doca between tracks



Mapping of the VertDoca to the Particle bank:

- Index 1 and 2 of the 2 particles in the VertDoca bank correspond to the row index (starts at 0) in the Particle bank.

Vertexing* for Lambda Reconstruction (RGK)

*** Charged tracks pair common vertex reconstruction**

- Selection of ep→ e ($p\pi^-$) X events using Fall18 RGK data
  - e- reconstructed in EC
  - e- reconstructed in FT (FT sample)
  - X required to be identified as kaon by the EB (no additional PID cuts → high pion contamination)
    - Subsequential PID cuts (reconstructed kaon mass) to clean up the sample
  - Require the vertex between p and π^- to be reconstructed with doca<5 cm

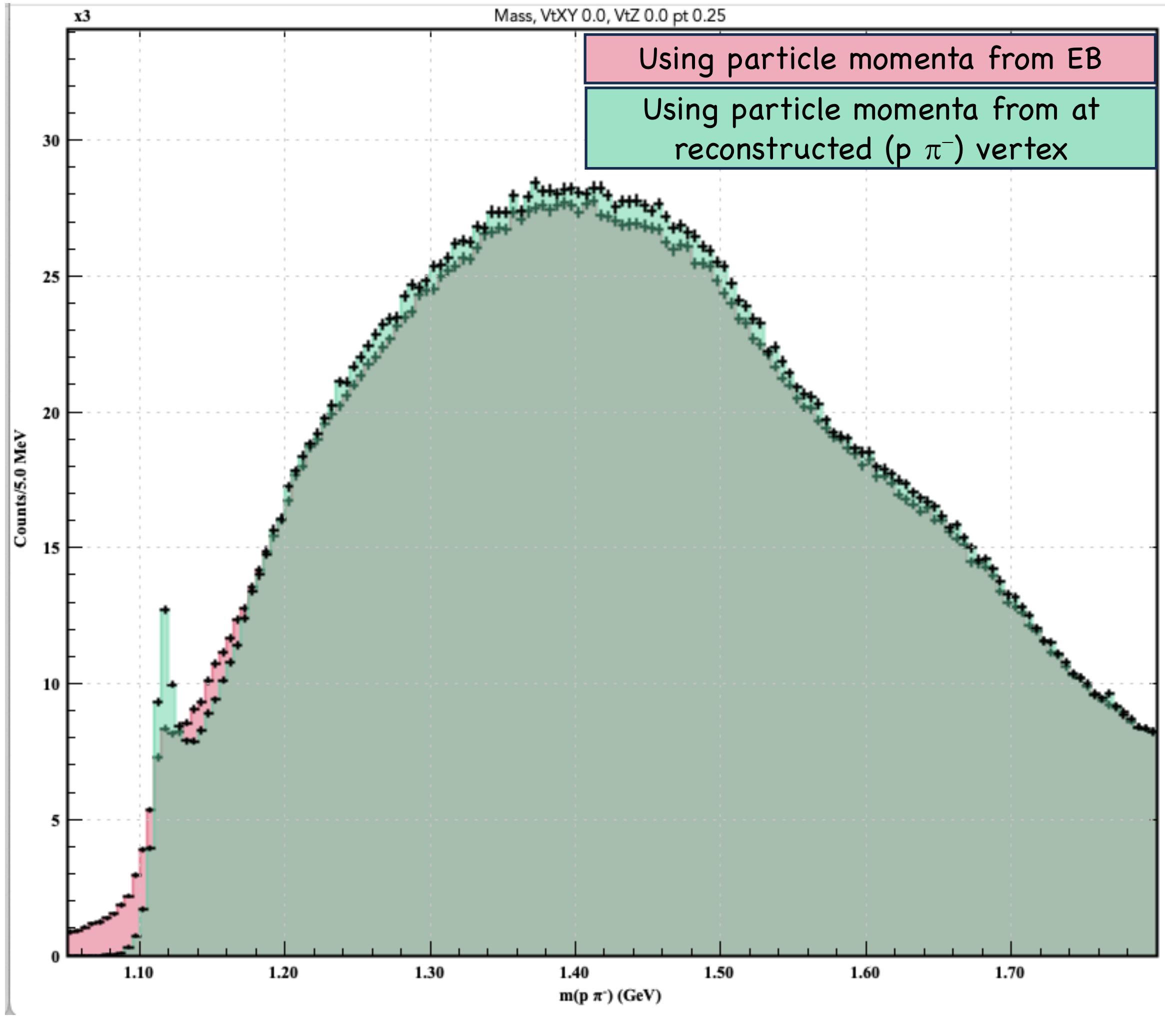
- Comparison of spectra using the momenta of the p and π^- corrected at the reconstructed vertex of the ($p\pi-$) pair to the spectra obtained using the momenta from the EB bank (REC::Particle), which is reported at the DOCA to the beamline (FD) or the using the Beam Spot (CD; momenta without Beam Spot constrained also saved)
  - Comparison of resolutions for different event selection criteria

- The reconstruction of the Λ→$p\pi^-$ candidate uses the momenta of the p and π^- at the reconstructed vertex
  - Signal to background ratios studied as a function of the vertex displacement with respect of a reference vertex (in this case the kaon, since the e- vertex is not determined for FT events)

Vertexing* for Lambda Reconstruction (RGK)

Distributions m(pπ⁻) using selection criteria:

- e in EC
- $p_T(p) > 250$ MeV
- Require K^+ in REC::Particle (EB)
    - Loose PID: kaon misID→high bg.



Failure to use the momenta reconstructed at the right position along the track trajectory, leads to degradation of the resolution of the reconstructed $(p\pi^-)$ invariant mass spectrum.

Under high background conditions, this results in a significant loss of signal.

Vertexing* for Lambda Reconstruction (RGK)

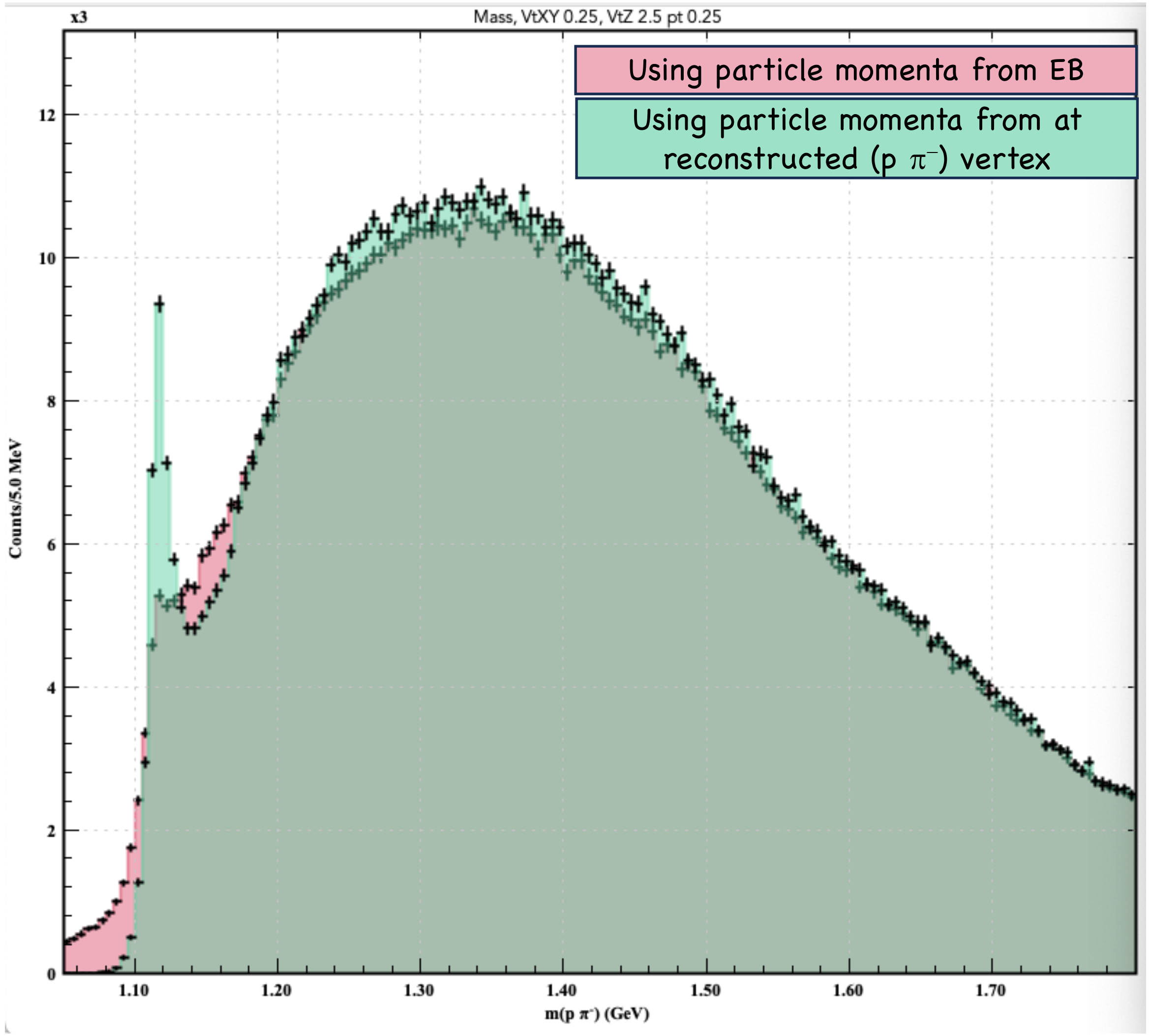
Selecting events with displaced (pπ⁻) vertexes *(wrt K⁺ track vertex)*

- 2.5 mm in XY
- 2.5 cm in Z

➢ To reduce *high-mass* background on the right-hand side of the expected peak

Distributions m(pπ⁻) using selection criteria:

- e in EC
- $p_T(p) > 250$ MeV
- Require K⁺ in REC::Particle (EB)
    - Loose PID: kaon misID→high bg.



Signal-to-background ratio improvement observed only when the correct momenta are used in the invariant mass computation

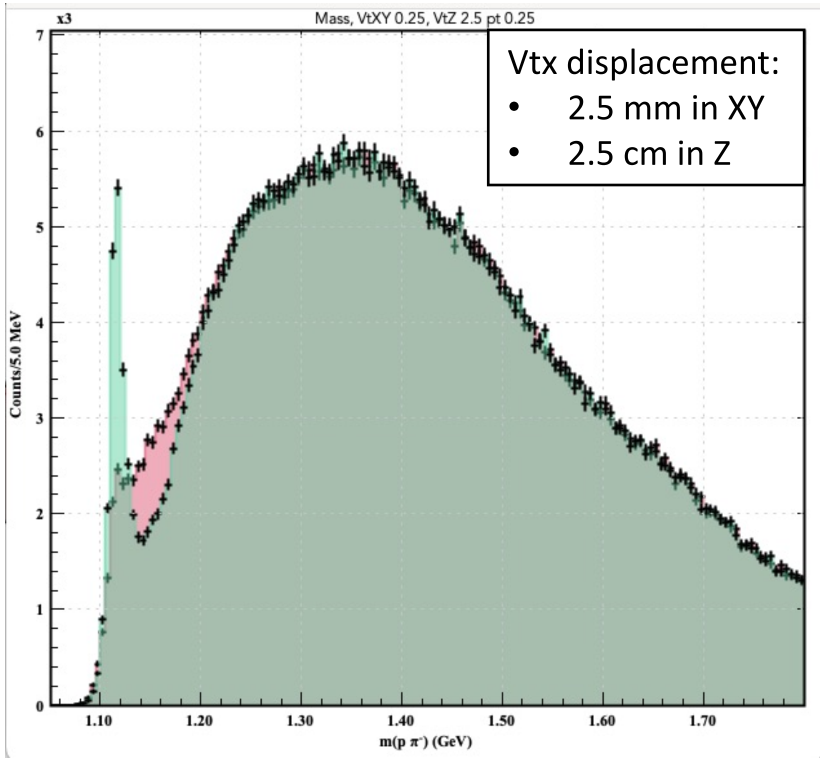
Both the p and the π^- reconstructed in the FD

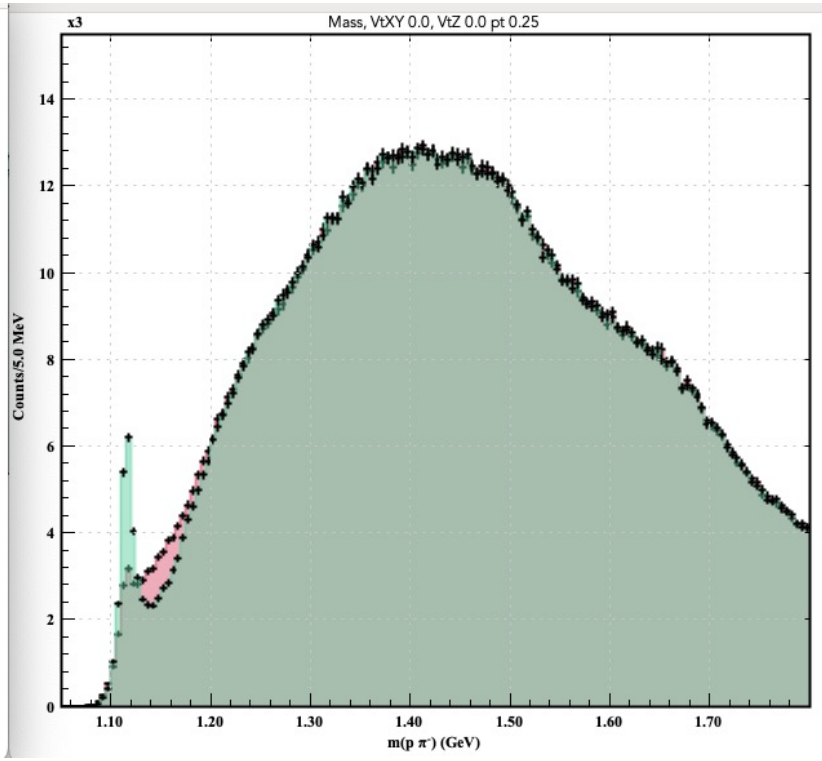
Distributions m(pπ–) using selection criteria:

- e in EC
- $p_T(p)$ > 250 MeV
- Require K^+ in REC::Particle (EB)
  - Loose PID: kaon misID→high bg.

Using particle momenta from EB

Using particle momenta from at reconstructed (p π–) vertex





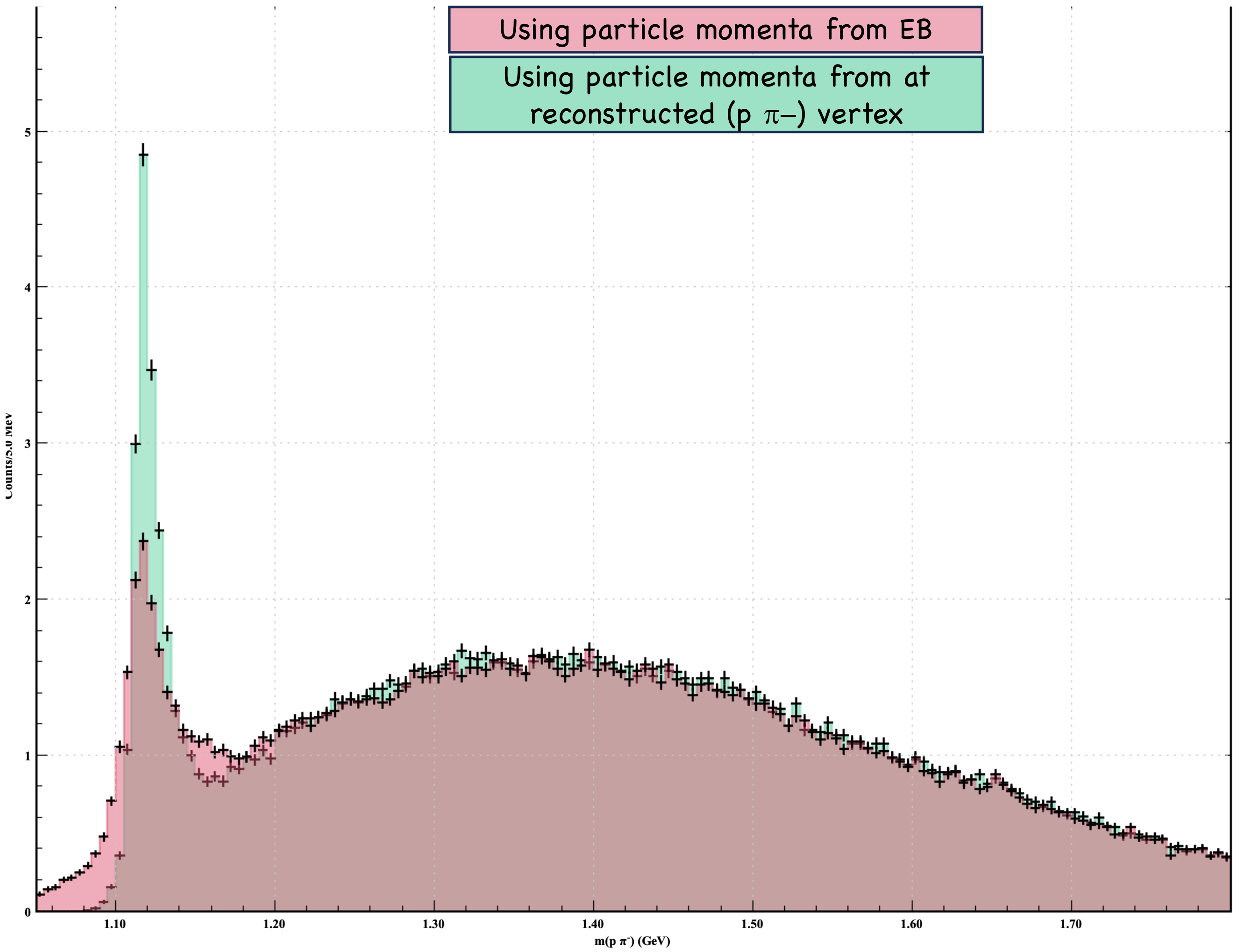
- Improved signal resolution with track pair vertexing – resulting from better momentum resolution in FD – not seen without track pair vertexing

Vertexing* for Lambda Reconstruction (RGK)

With the K^+ **reconstructed in the FD**, the peak is visible using the particle momenta from EB, but with worse resolution

Distributions $m(p\pi^-)$ using selection criteria:

- e in EC
- $p_T(p)$ > 250 MeV
- Require K^+ in REC::Particle (EB)
  - Require K in FD
  - Chi2pid(K) < 15



- Without track pair vertexing, exclusivity cut (i.e. requiring a clean kaon from the FD in the event) needed to observe a Lambda signal.

Analysis with Detached Vertex Finder

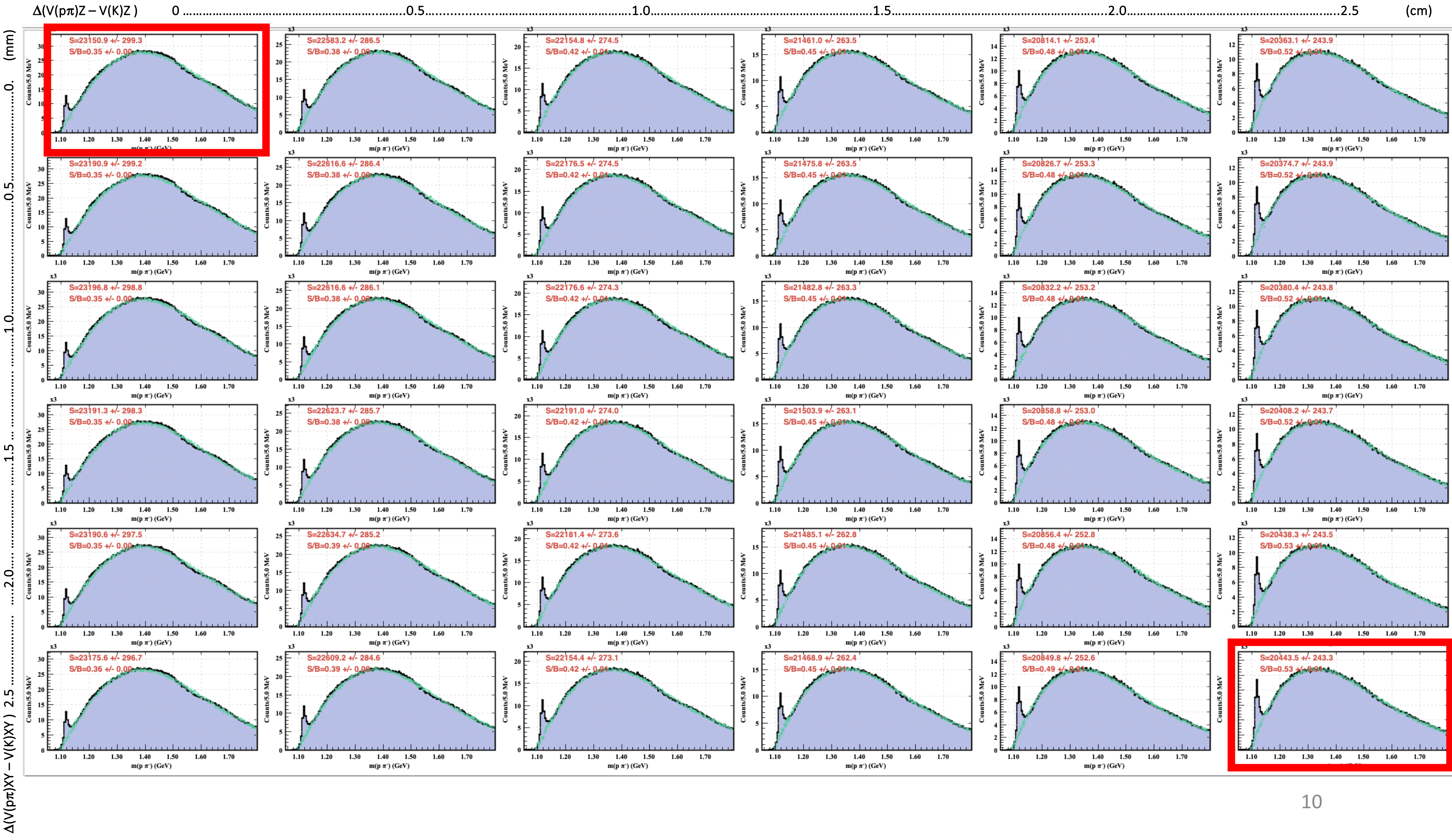
RGK Fall18
e- in ECAL

reaction:

ep →e(Λ→pπ⁻)K⁺

- e in EC
- $p_T(p)$ > 250 MeV
- Require K⁺ in REC::Particle (EB)
  - Loose PID
- Decay vertex displacement wrt to K⁺ (comparison with FT events)
- Vtx displacement cuts

Under higher background conditions, Vtx cuts useful to isolate the signal



Analysis with Detached Vertex Finder

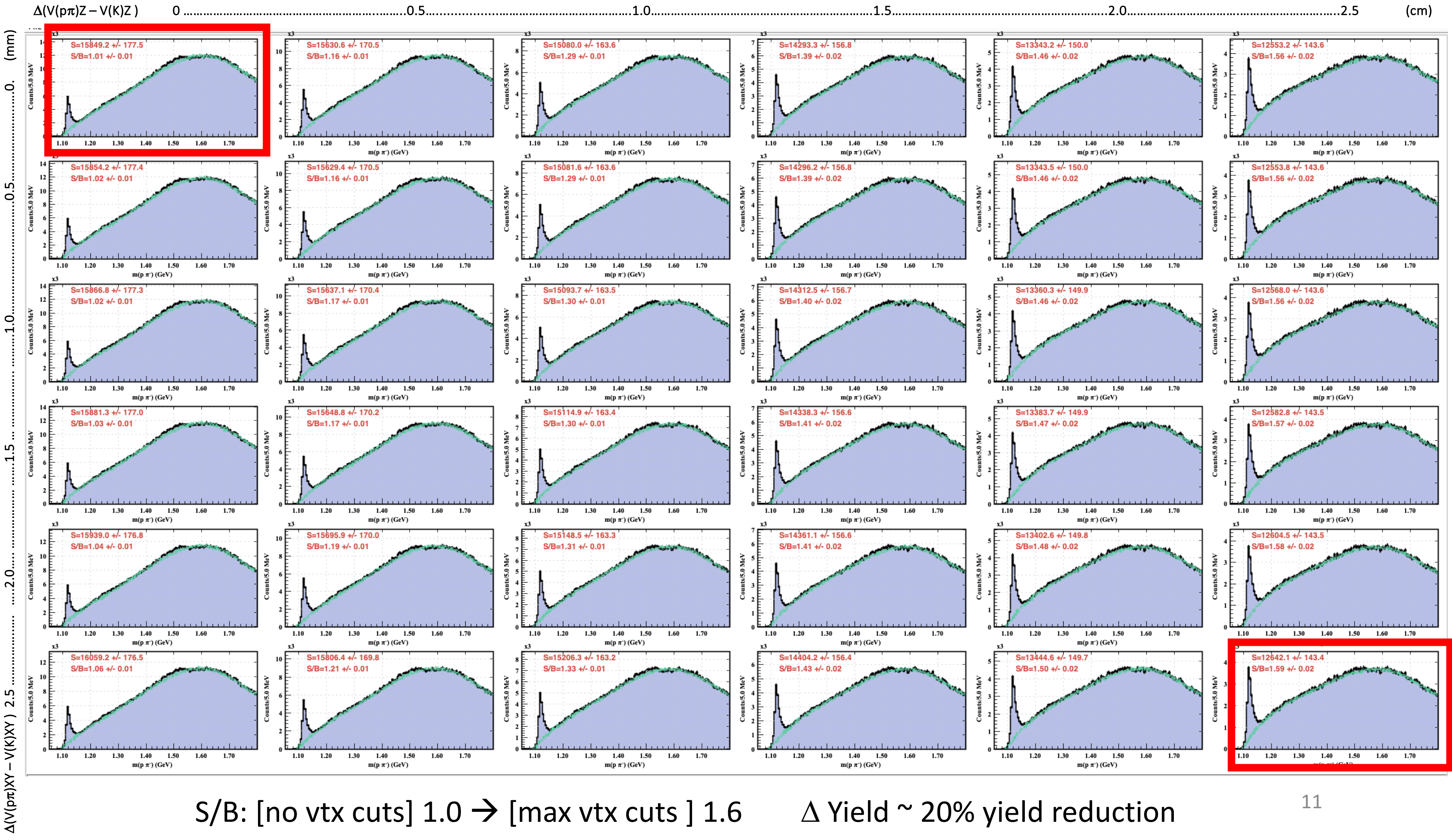
RGK Fall18
e- in FT

reaction:

ep → e(Λ → pπ^-)K^+

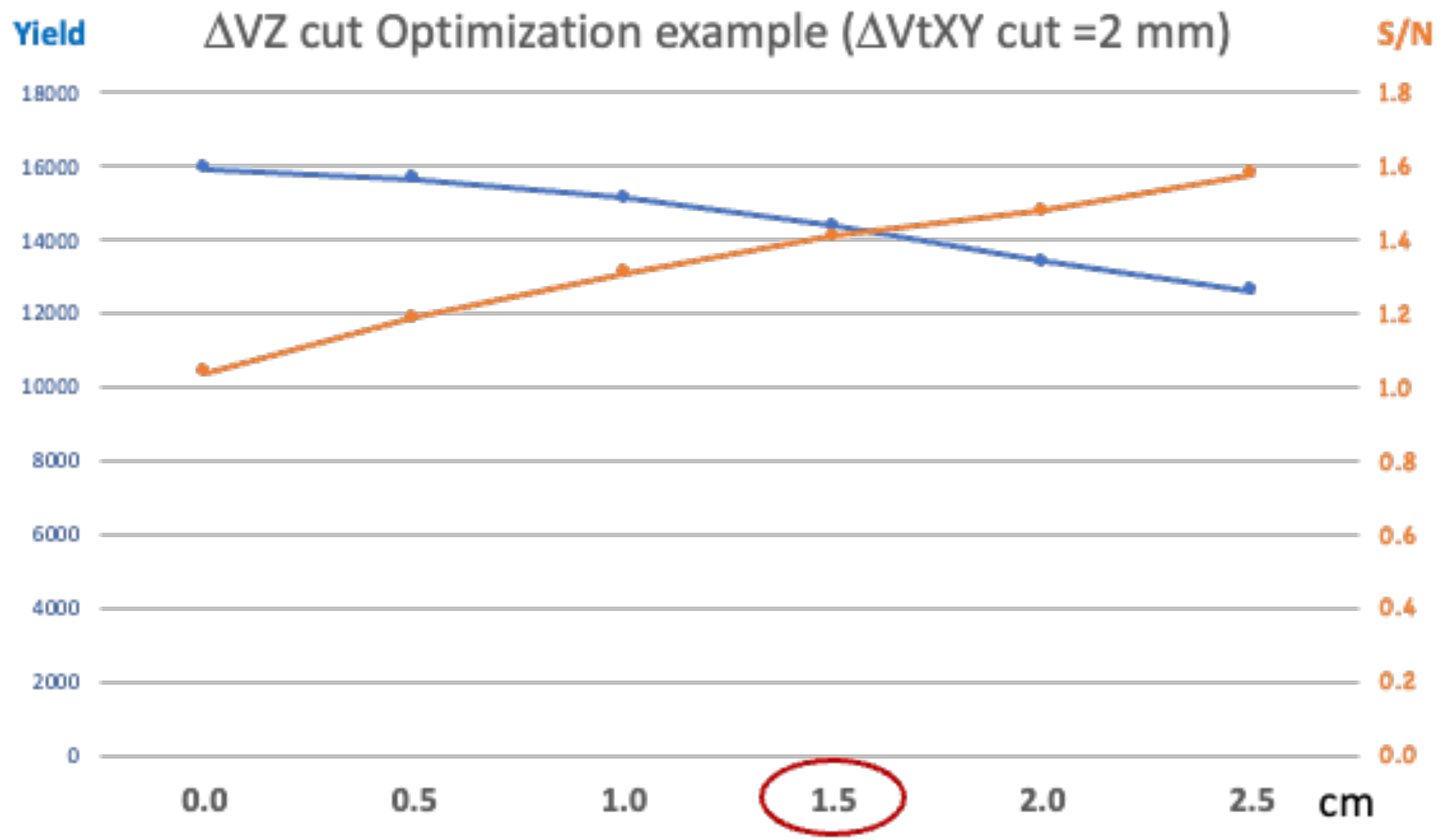
- **e in FT**
- $p_T(p)$ > 250 MeV
- Require K^+ in REC::Particle (EB)
  - Loose PID
- Decay vertex displacement wrt to K^+ Vtx displacement cuts

If signal well isolated, but significant background under the peak, Vtx cuts optimization may be helpful if signal purity is needed for analysis



S/B: [no vtx cuts] 1.0 → [max vtx cuts] 1.6   Δ Yield ~ 20% yield reduction

Analysis with Detached Vertex Finder



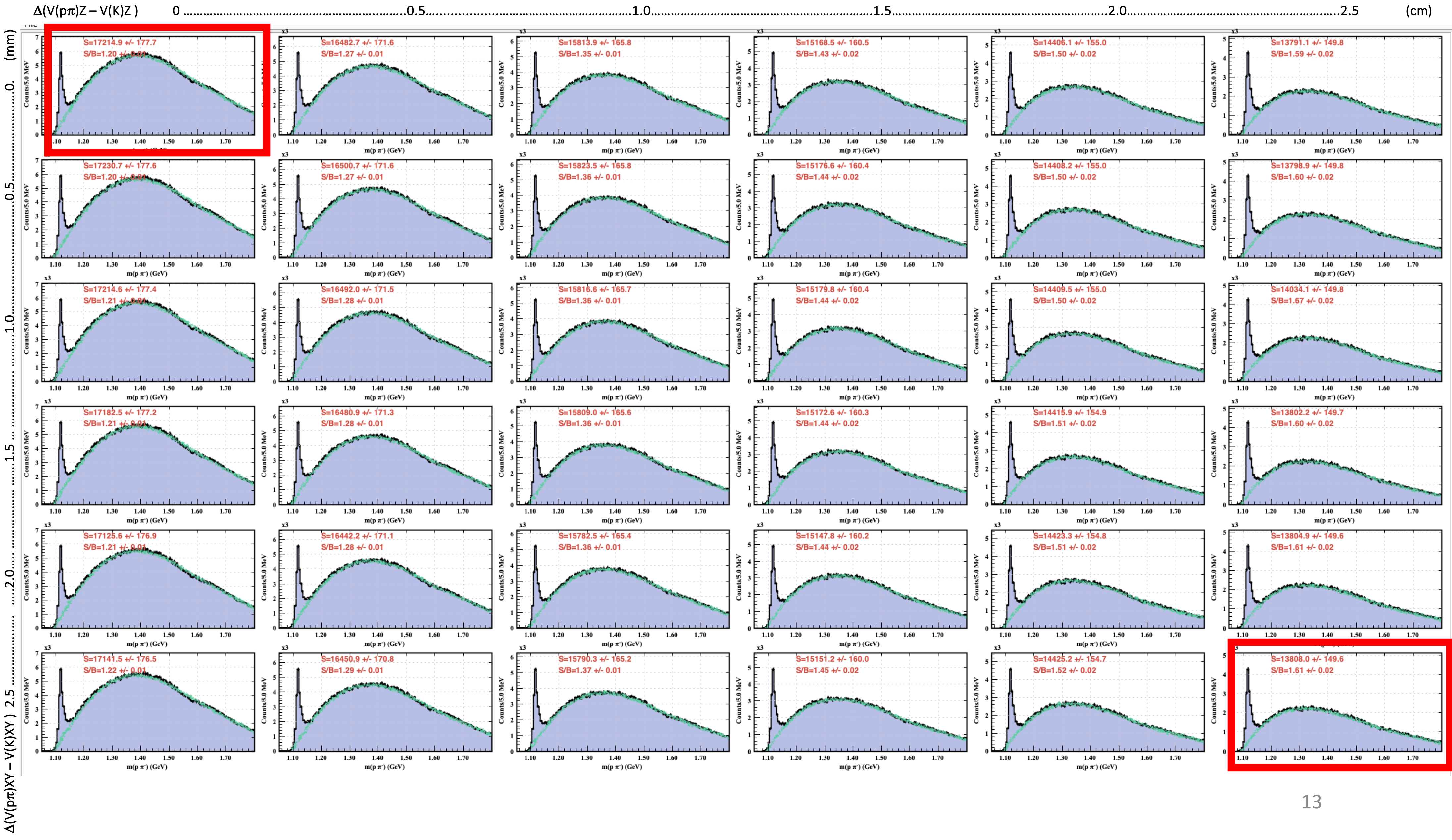
Analysis with Detached Vertex Finder

RGK Fall18
e- in ECAL

reaction:

ep → e(Λ→pπ⁻)K⁺

- e in EC
- $p_T(p)$ > 250 MeV
- Require K⁺ in REC::Particle (EB)
  - **PID cut: m_rec(K) w/in 35 MeV of PDG mass**
- Decay vertex displacement wrt to K⁺ (comparison with FT events)
- Vtx displacement cuts



Inv. Mass spectrum already well isolated – not much benefit from Vtx cuts

Analysis with Detached Vertex Finder

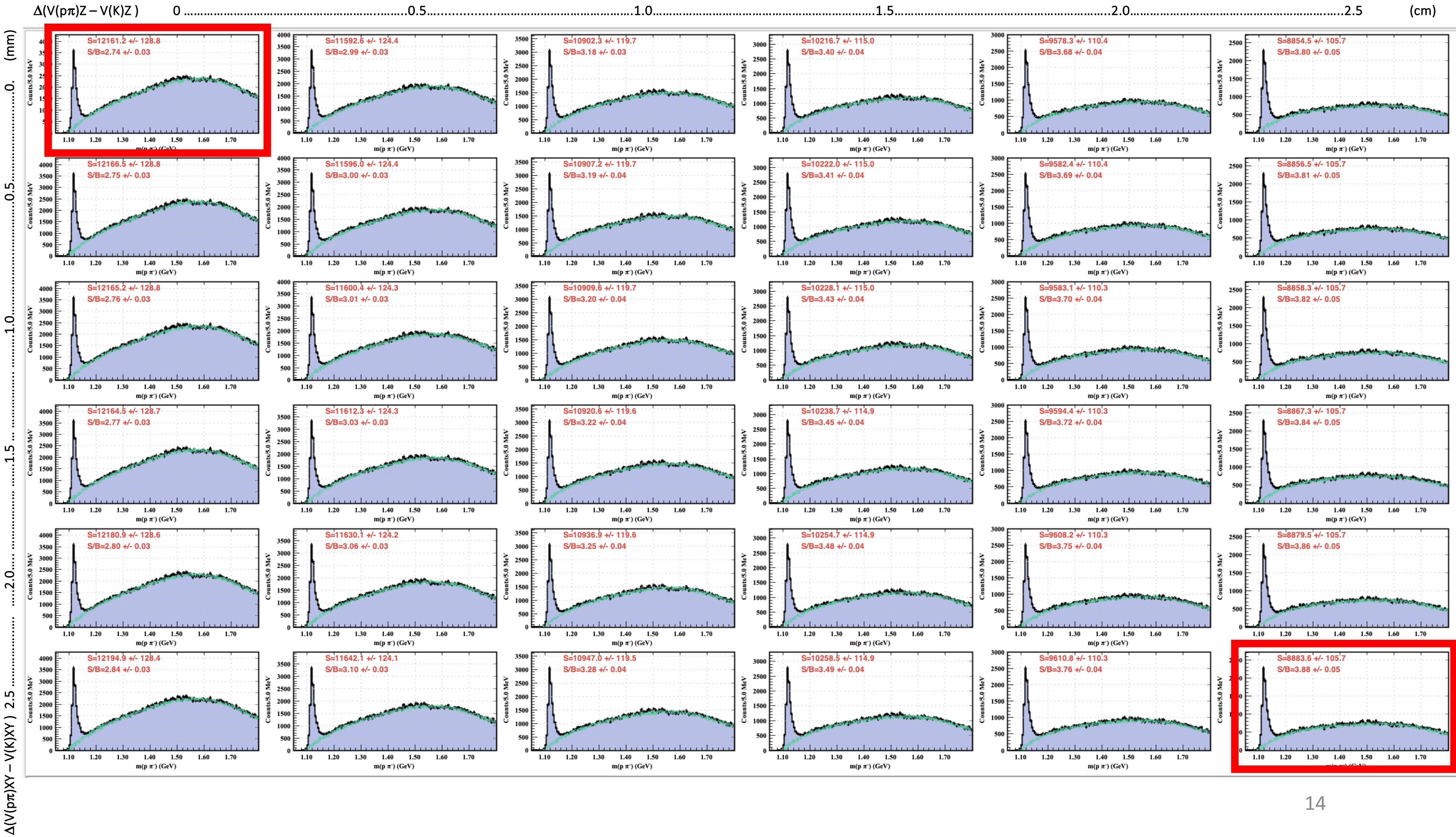
RGK Fall18
e- in FT

reaction:

ep → e(Λ → pπ⁻)K⁺

- **e in FT**
- $p_T(p)$ > 250 MeV
- Require K⁺ in REC::Particle (EB)
  - **PID cut: m_rec(K) w/in 35 MeV of PDG mass**
- Decay vertex displacement wrt to K⁺ Vtx displacement cuts

Inv. Mass spectrum already clean – not much benefit from Vtx cuts



Analysis with Detached Vertex Finder

RGK Fall18
e- in ECAL

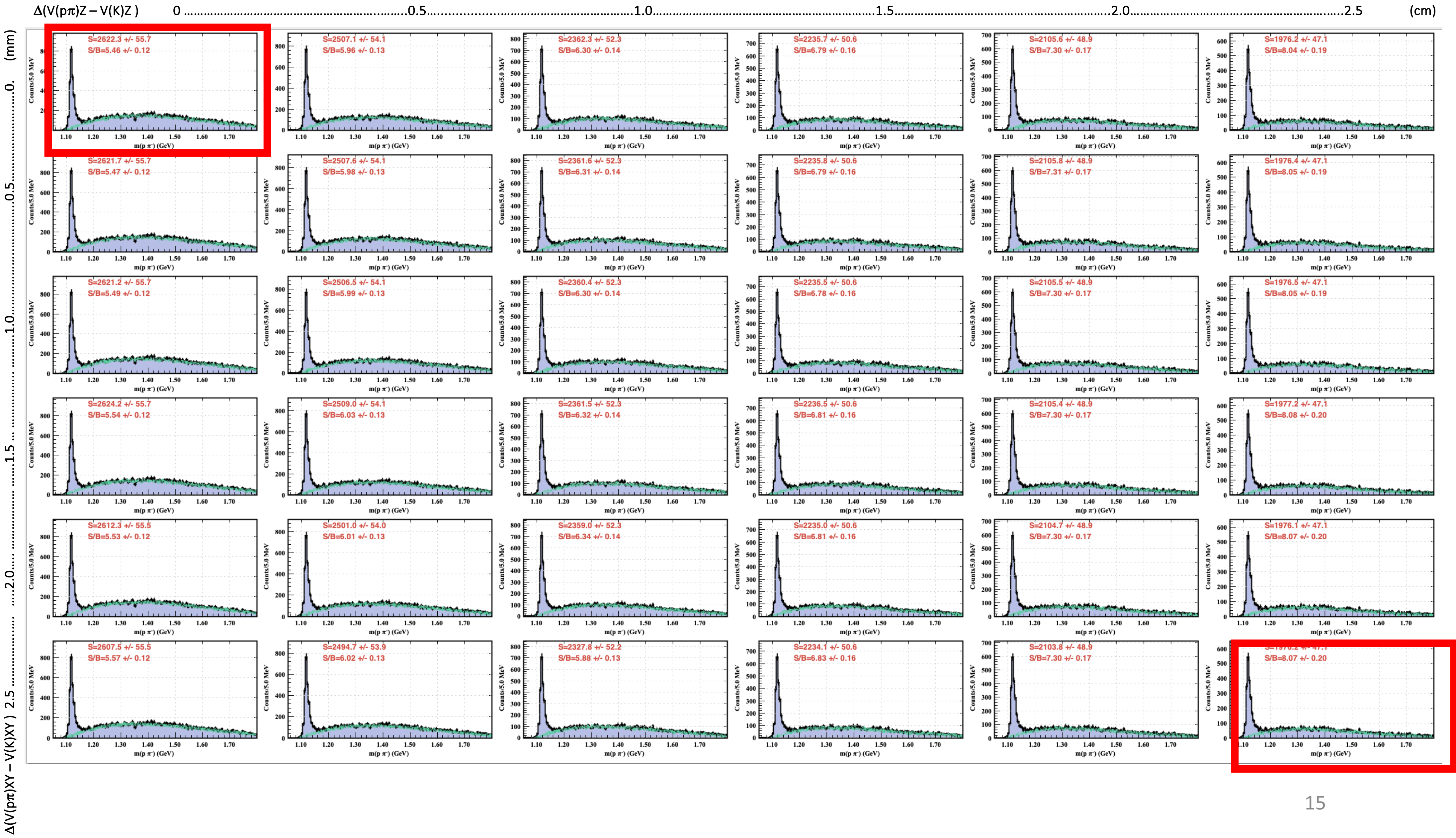
reaction:

ep → e(Λ → pπ⁻)K⁺

- e in EC
- $p_T(p)$ > 250 MeV
- Require K^+ in REC::Particle (EB)
  - PID cut: m_rec(K) w/in 35 MeV of PDG mass
- Exclusivity cut:

MM(epπ–) with 35 MeV of PDG kaon mass

- Decay vertex displacement wrt to K^+ (comparison with FT events)
- Vtx displacement cuts



Analysis with Detached Vertex Finder

RGK Fall18
e- in FT

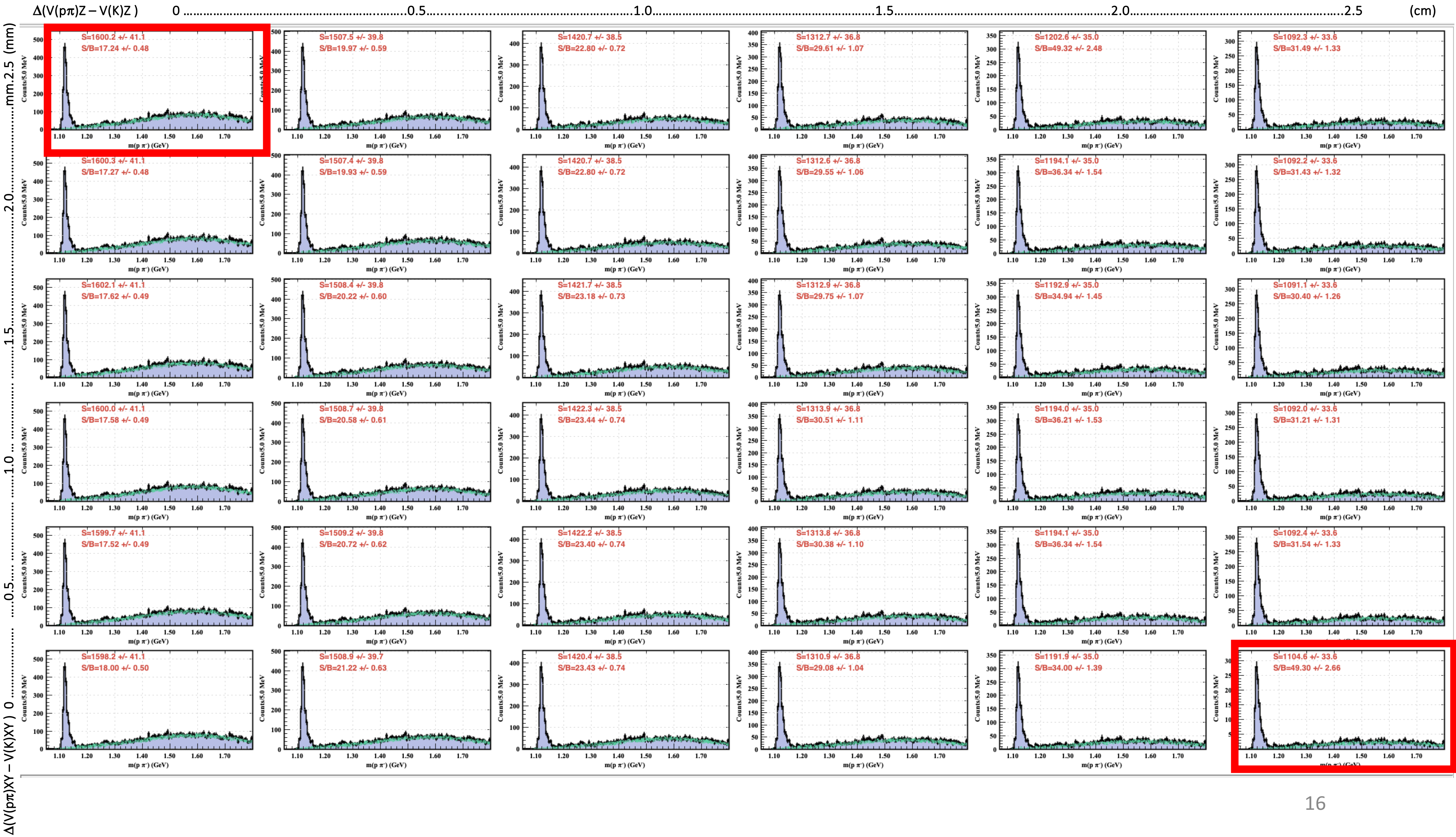
reaction:

ep → $e(\Lambda \rightarrow p\pi^-)K^+$

- **e in FT**
- $p_T(p)$ > 250 MeV
- Require K^+ in REC::Particle (EB)
  - PID cut: m_rec(K) w/in 35 MeV of PDG mass
- Exclusivity cut:

  MM(epπ–) with 35 MeV of PDG kaon mass
- Decay vertex displacement wrt to K^+

  Vtx displacement cuts



Not much benefit from Vtx cuts

Analysis with Detached Vertex Finder

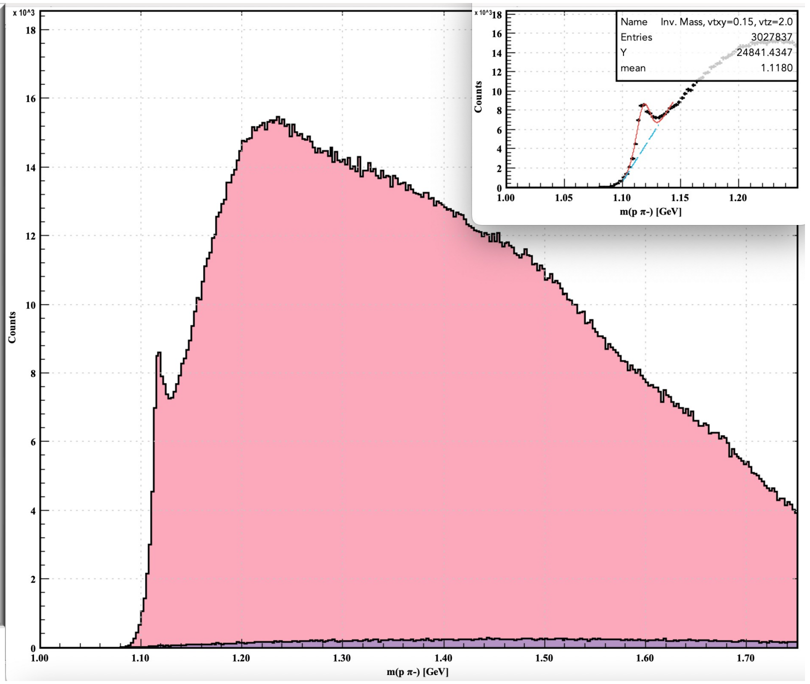
- Results without requiring a kaon in the event
  - Although the background is higher, clear signal obtained
  - Possibility to study various channels where S/B ration and signal resolution essential

RGB Spring19
e- in ECAL

Decay:

ep → e($\Lambda \rightarrow p\pi^-$)**X**

- e in EC
- No requirements of additional particles in the event
- p in FD, π^- in CD
- Vtx displacement cuts
  - VtXY>1.5 mm
  - VtZ>2.0 cm

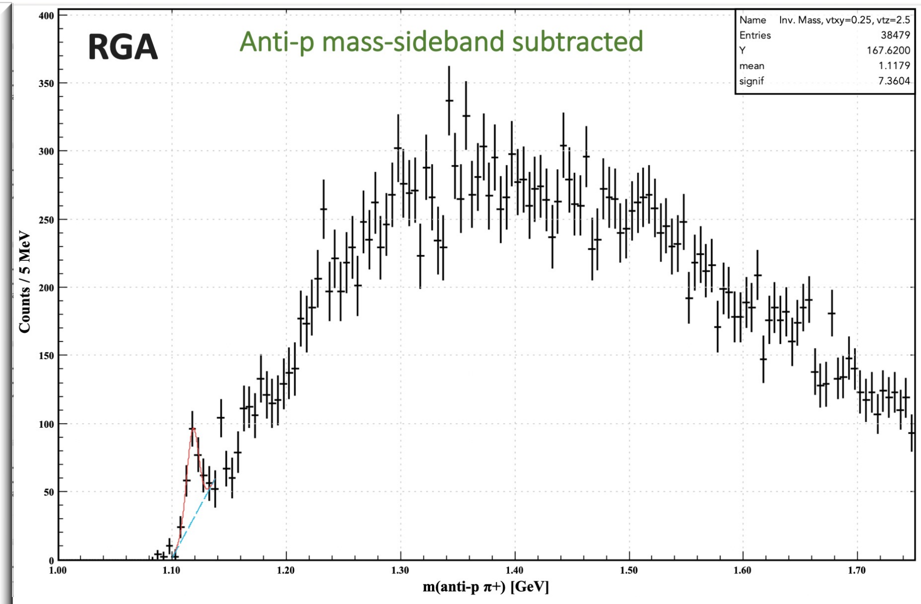


RGA Spring19
e- in ECAL

Decay:

ep → e($\bar{\Lambda} \rightarrow \bar{p}\pi^+$)**X**

- e in EC
- MM($\bar{p}\pi^+$)>2m_p+0.35 GeV
- $p_T(\bar{p})$ > 500 MeV
- No requirements of additional particles in the event
- $\bar{p}$ in FD
- Vtx displacement cuts
  - VtXY>2.5 mm
  - VtZ>2.5 cm



Vertexing for Lambda Reconstruction (RGK)

Cutting on displaced vertex leads to

- Better signal to background ratio
  - For some channels they are needed to observe a signal

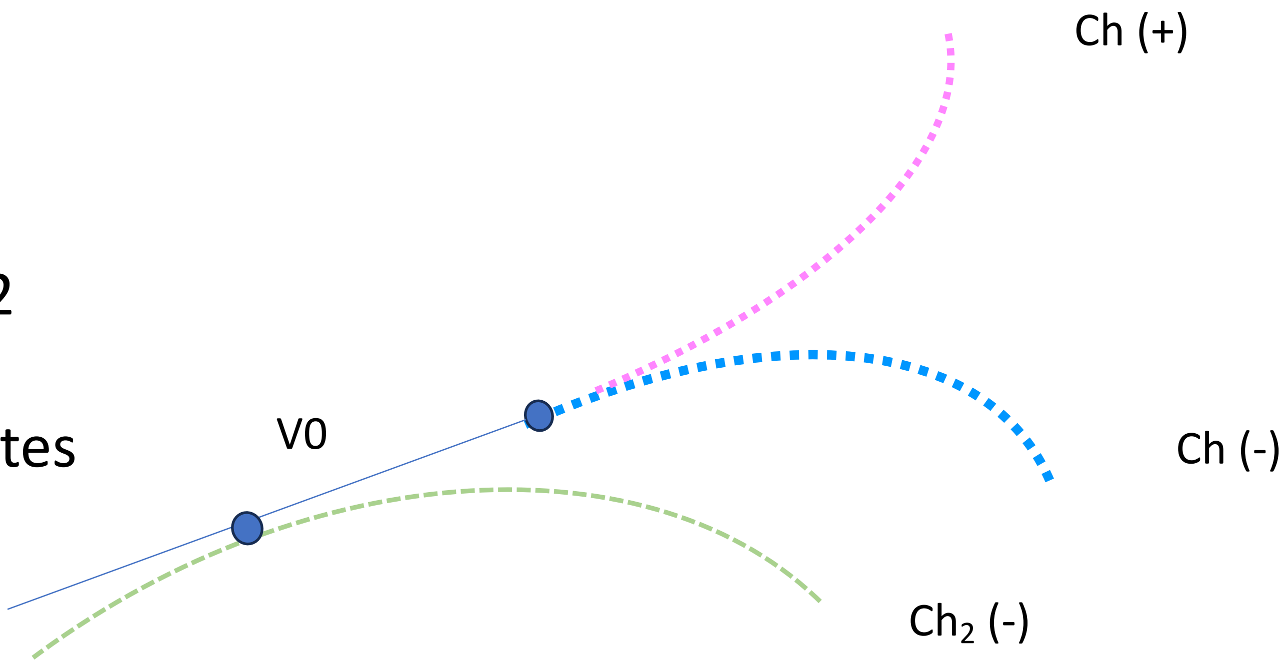
- Some loss of events
  - Expected
  - In some instances these cuts result in reduced significance and are not useful.

Selection of these cut reaction and kinematics dependent

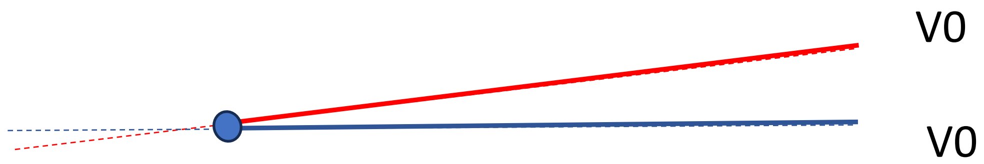
- Must be evaluated based on other cuts (PID)

Next … Sequential Decays

- V0 + Ch (i.e. $\Omega^- \rightarrow \Lambda(\rightarrow p\ \pi^-)\ K^-$)
  - Create a trajectory for V0
  - Use trajectory of Ch
  - Same interpolation method between 2 trajectories
  - Vertex of Ch_2 (-) and momentum updates



- V0 + neutral (i.e. $\Xi^0 \rightarrow \Lambda(\rightarrow p\ \pi^-)\ \pi^0\ (\rightarrow\gamma\gamma)$) or V0+V0 (i.e. $\Lambda(\rightarrow p\ \pi^-)\ \bar{\Lambda}(\rightarrow \bar{p}\ \pi^+)$)
  - DOCA between 2 lines



➢ In development in my analysis package, algorithm to be included as methods in Vtx package
➢ Validation in progress

Banks Structures: Storing Decay Chains Info

REC::VertDoca

next | prev | seq # 5 | true # 61971

	index1	index2	x	y	z	x1	y1	z1	cx1	cy1	cz1	x2	y2	z2	cx2	cy2	cz2	r
1	0	3	0.23567	0.19718	-4.84147	0.02829	-0.12346	-4.88774	-1.06517	1.08930	6.48670	0.44304	0.51783	-4.79521	0.77950	-0.37302	1.64688	0.76931
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REC::Particle

next | prev | seq # 5 | true # 61971

	pid	px	py	pz	vx	vy	vz	charge	beta	chi2pid	status
1	11	-1.06468	1.08978	6.48670	-0.00368	-0.09075	-4.69303	-1	1.00000	0.22344	-2232
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6	22	0.07992	-0.01862	0.12999	-0.00368	-0.09075	-4.69303	0	0.91234	9999.00000	2010

ANAL::Particle

next | prev | seq # 5 | true # 61971

	idx	pid	emc	erec	e	ovx	ovy	ovz	px	py	pz	upx	upy	upz	vx	vy	vz	r	charge	mass	ndau	dau1idx	dau2idx	det
1	200	999	3.8590	3.8604	3.8757	-0.003	-0.090	-4.693	1.6351	-0.886	2.9581	1.6356	-0.884	2.9581	-1.130	-0.390	-6.673	3.6096	-1	1.6769	2	100	2	-1
2	100	3122	2.8761	2.9169	2.8928	-1.130	-0.390	-6.673	1.1918	-0.607	2.2888	1.1923	-0.605	2.2888	-2.080	-0.514	-8.203	4.0985	0	1.1579	2	4	3	-1
3	4	2212	2.0831	2.1056	2.0831	-2.080	-0.514	-8.203	0.7675	-0.397	1.6468	0.7779	-0.376	1.6468	-1.158	1.3149	-8.204	0.0	1	0.9382	0	0	0	1
4	3	-211	0.8097	0.8113	0.8097	-2.080	-0.514	-8.203	0.4242	-0.209	0.6419	0.4143	-0.228	0.6419	-3.003	-2.344	-8.201	0.0	-1	0.1395	0	0	0	1
5	2	-321	0.9829	0.9434	0.9829	-1.130	-0.390	-6.673	0.4433	-0.279	0.6693	0.4433	-0.279	0.6693	-0.180	-0.265	-5.144	0.0	-1	0.4936	0	0	0	0

idx: REC::Particle row

ov: Parent Vtx

p: P corrected (at Vtx)

up: P uncorrected

v: Vtx (detached) or from REC banks for non-detached trks

dauIdx: REC::Particle row

emc: mass-constrained energy

erec: reconstructed energy (EB)

e: energy used in anal (MCst or rec.)

det: FD (1) or CD (0) det. system

Reaction P → $D_1 + D_2$

$D_1 \rightarrow G_1 + G_2$

REC::ANAL structure:

Row 1: P

Row 2: D_1

Row 3: G_1

Row 4: G_2

Row 5: D_2

Reaction P → $D_1 + D_2$

$D_1 \rightarrow G_1 + G_2$

$D_2 \rightarrow G_3 + G_4$

REC::ANAL structure:

Row 1: P

Row 2: D_1

Row 3: G_1

Row 4: G_2

Row 5: D_2

Row 6: G_3

Row 7: G_4

SUMMARY

- Vertex reconstruction implemented for opposite-charge track pairs
  - Creates entries in REC::VertDoca bank
  - Lambda invariant mass reconstruction using this bank
    - Significant improvement in signal resolution
    - Vertex cuts can potentially improve signal significance (background reduction)

- Further development for combination of various track pairs

- Code currently available in a branch under coatjava distribution
  - detachedVtx
  - Not yet merged
  - Reconstruction time profiling to be done
    - Uses swimming which is compute intensive

BACK-UP SLIDES

Vertexing* for Lambda Reconstruction (RGK)

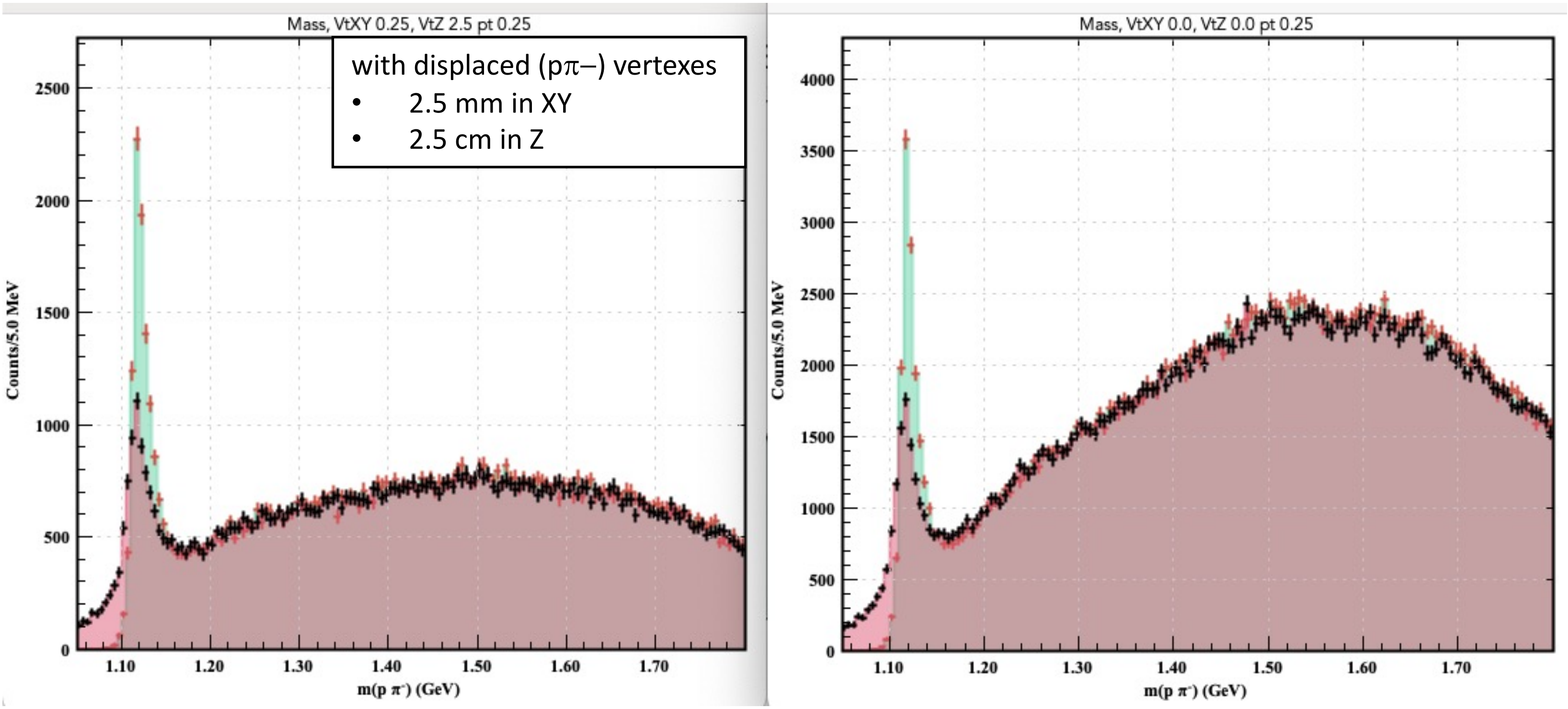
Using particle momenta from EB

Using particle momenta from at reconstructed (p π–) vertex

Cleaner spectrum

Distributions m(pπ–) using selection criteria:

- **e in FT**
- $p_T(p) > 250$ MeV
- Require K^+ in REC::Particle (EB) with chi2pid<15 and to be w/in 35 MeV of PDF mass



- Improved signal resolution with momenta obtained with decay particles momenta corrected at the vertex