

Analysis of $\bar{p}p \rightarrow \Xi^+ \Xi^-$ (1690)

Reconstruction and Background Studies

André Zambanini

8 September 2015

54. PANDA Meeting (GSI), Hyperon Session

Outline

- Motivation & simulation setup
- Reconstruction
- Background studies
- Summary

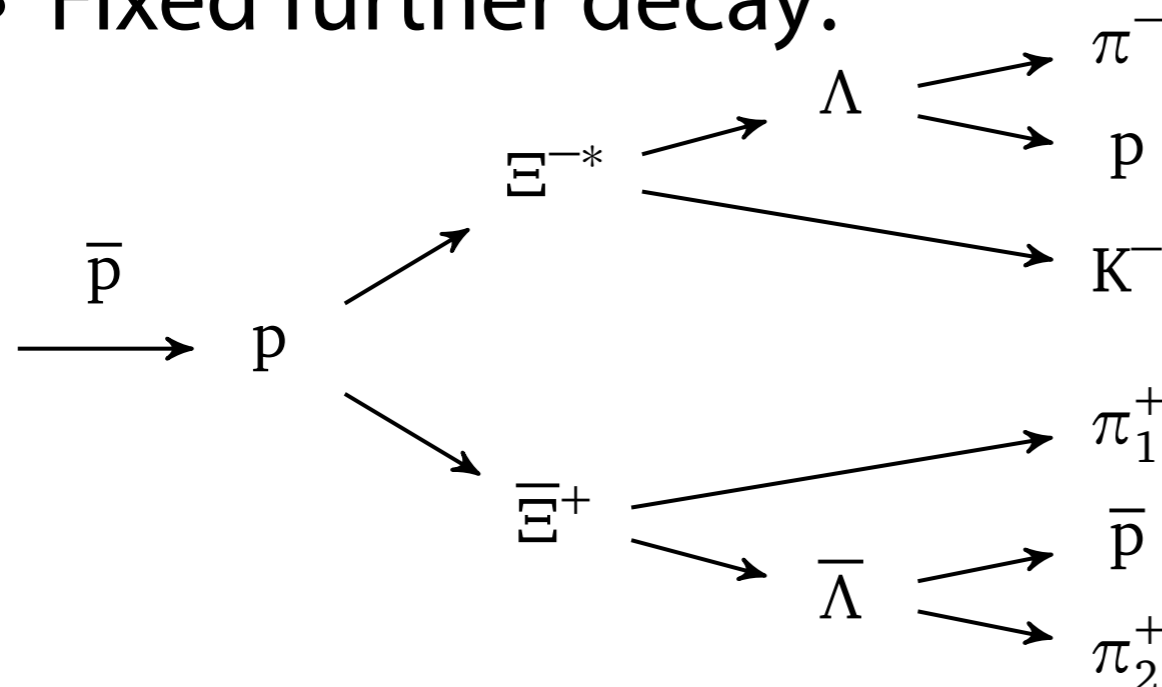
Investigated Channel

- Excited cascade: $\Xi^+\Xi^-(1690)$
 - Not much is known for $\Xi^-(1690)$
 - Threshold at 3012 MeV (J/ Ψ : 3097 MeV)
 - Beam momentum: 4.1 GeV/c ($\sqrt{s} = 3106$ MeV)

$\Xi(1690)$	$I(J^P) = \frac{1}{2}(??)$	
Mass $m = 1690 \pm 10$ MeV [c]		
Full width $\Gamma < 30$ MeV		
$\Xi(1690)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Lambda \bar{K}$	seen	240
ΣK	seen	70
$\Xi \pi$	seen	311
$\Xi^- \pi^+ \pi^-$	possibly seen	213

<http://pdg.lbl.gov/>, summary tables, generated on 2015-02-24

- Fixed further decay:



Note: Ξ^{-*} in my case always $\Xi^-(1690)$.

Event Generator: EvtGen
 Beam Momentum: 4.1 GeV/c
 FairSoft/FairRoot: mar15
 PandaRoot: trunk (r27694)
 Track Finding/PID: ideal

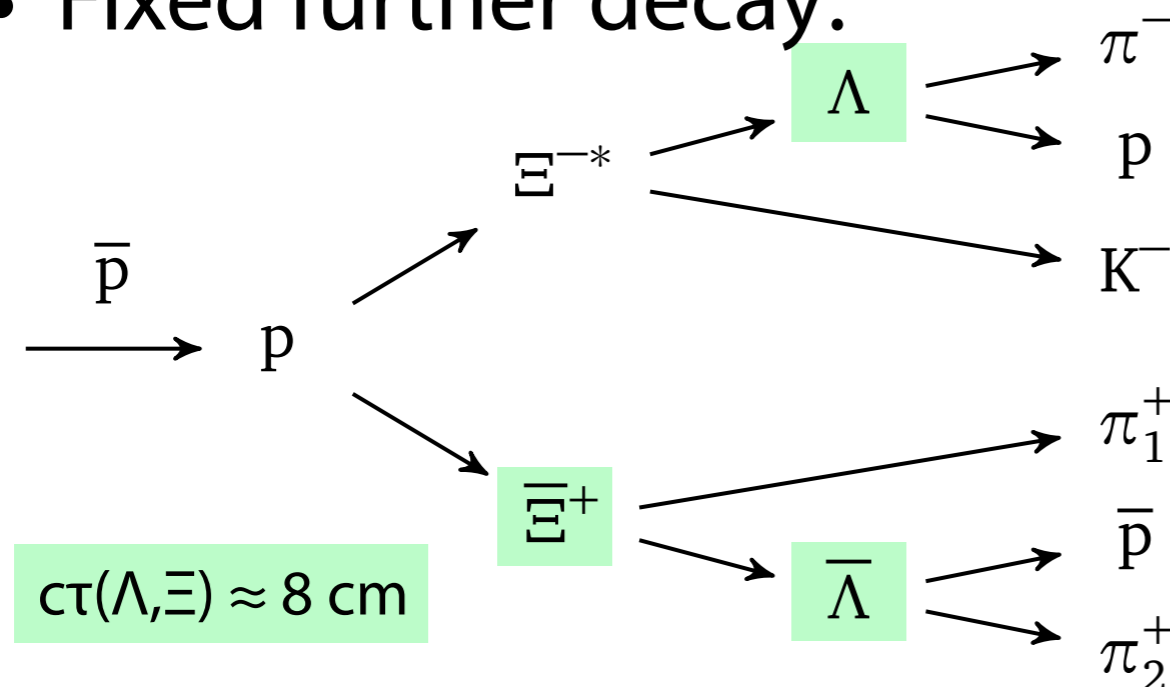
Investigated Channel

- Excited cascade: $\Xi^+\Xi^-(1690)$
 - Not much is known for $\Xi^-(1690)$
 - Threshold at 3012 MeV (J/ Ψ : 3097 MeV)
 - Beam momentum: 4.1 GeV/c ($\sqrt{s} = 3106$ MeV)

$\Xi(1690)$	$I(J^P) = \frac{1}{2}(??)$	
Mass $m = 1690 \pm 10$ MeV [c]		
Full width $\Gamma < 30$ MeV		
$\Xi(1690)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Lambda\bar{K}$	seen	240
ΣK	seen	70
$\Xi\pi$	seen	311
$\Xi^-\pi^+\pi^-$	possibly seen	213

<http://pdg.lbl.gov/>, summary tables, generated on 2015-02-24

- Fixed further decay:



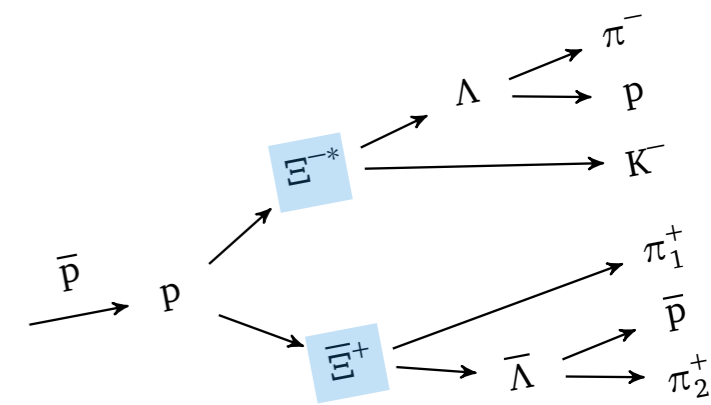
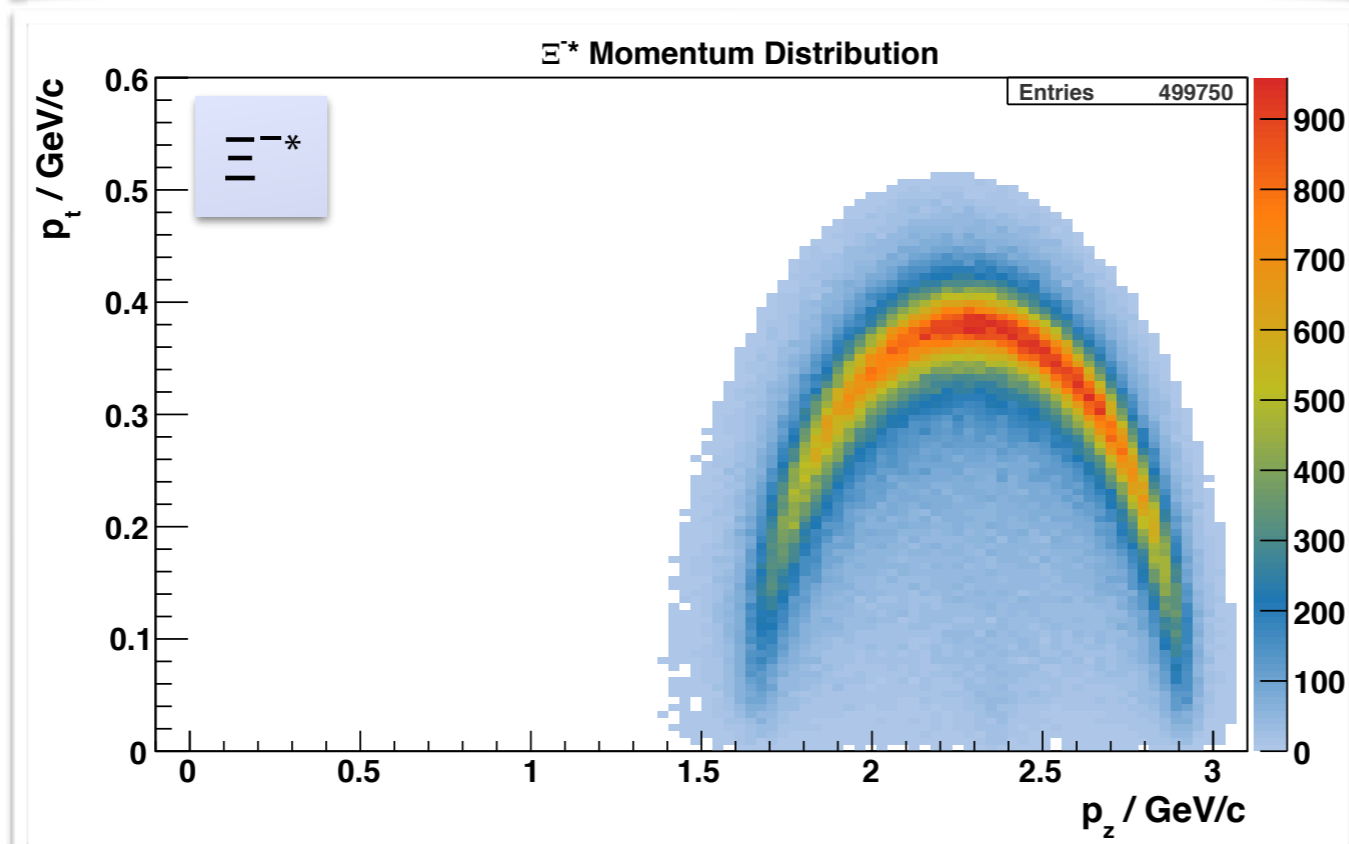
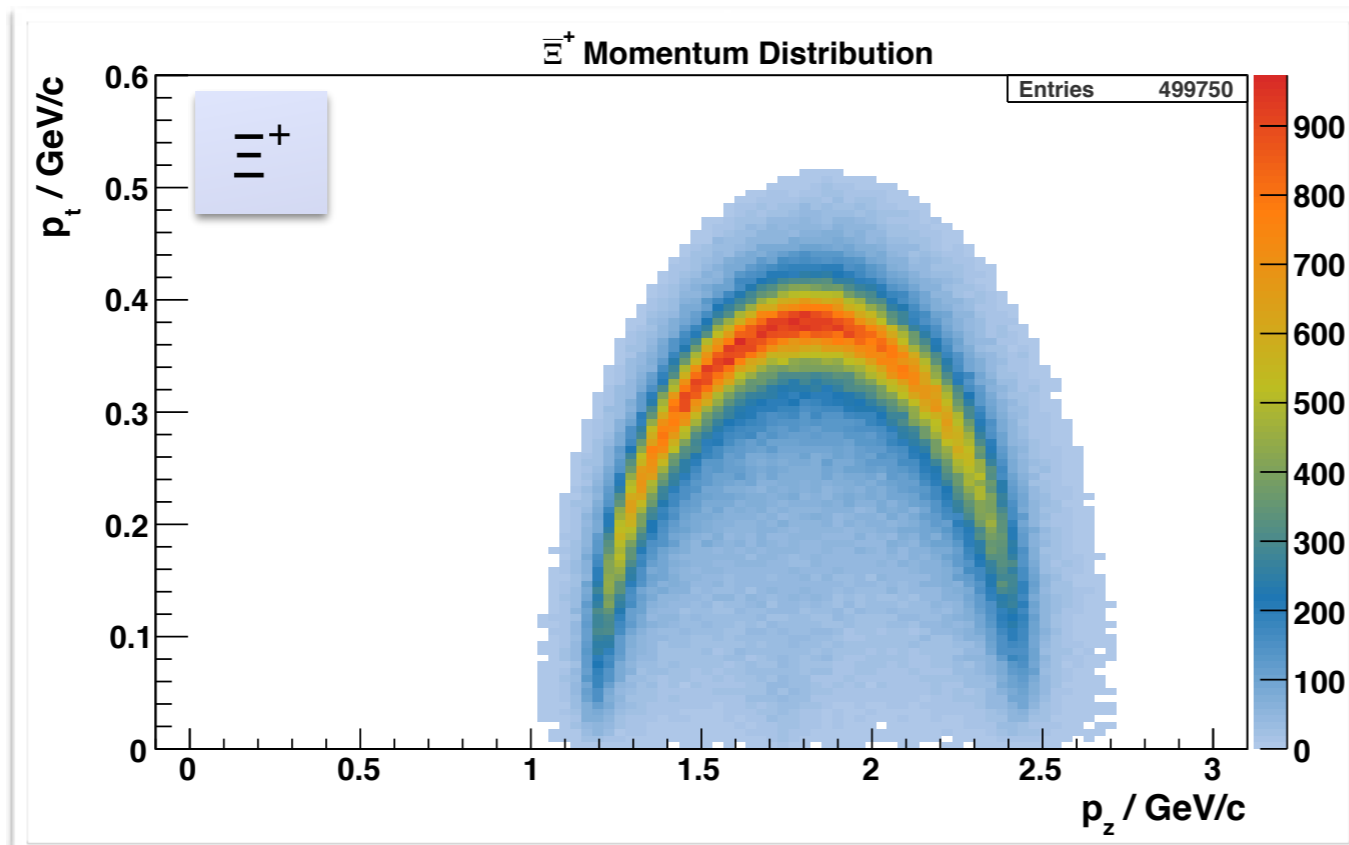
Note: Ξ^{*-} in my case always $\Xi^-(1690)$.

Event Generator: EvtGen
 Beam Momentum: 4.1 GeV/c
 FairSoft/FairRoot: mar15
 PandaRoot: trunk (r27694)
 Track Finding/PID: ideal

SIMULATION

EvtGen & Detector Response

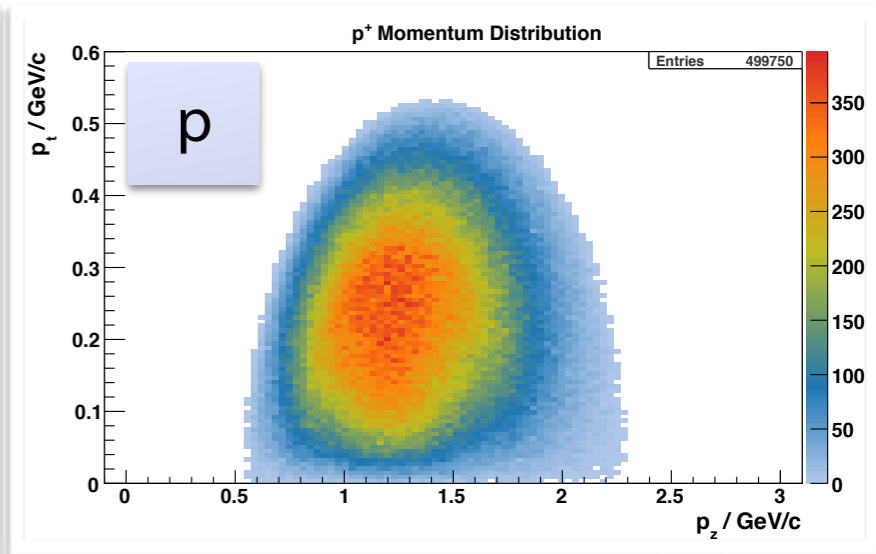
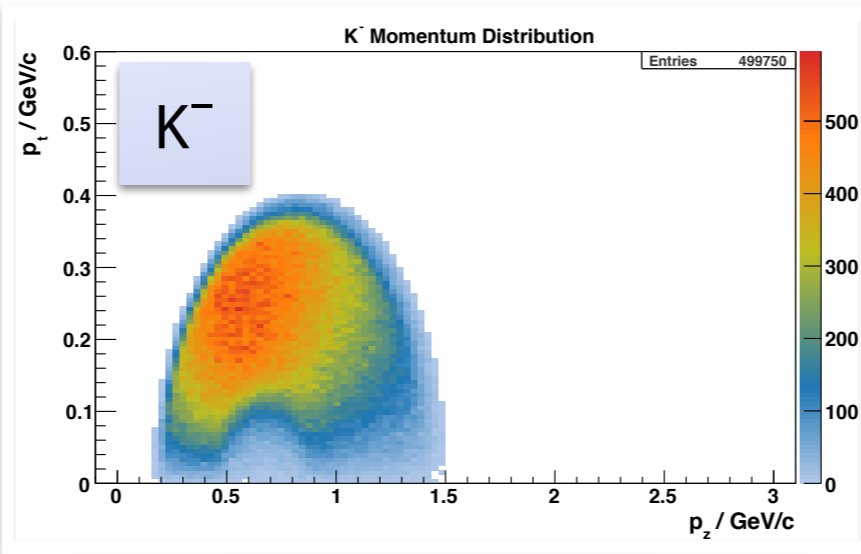
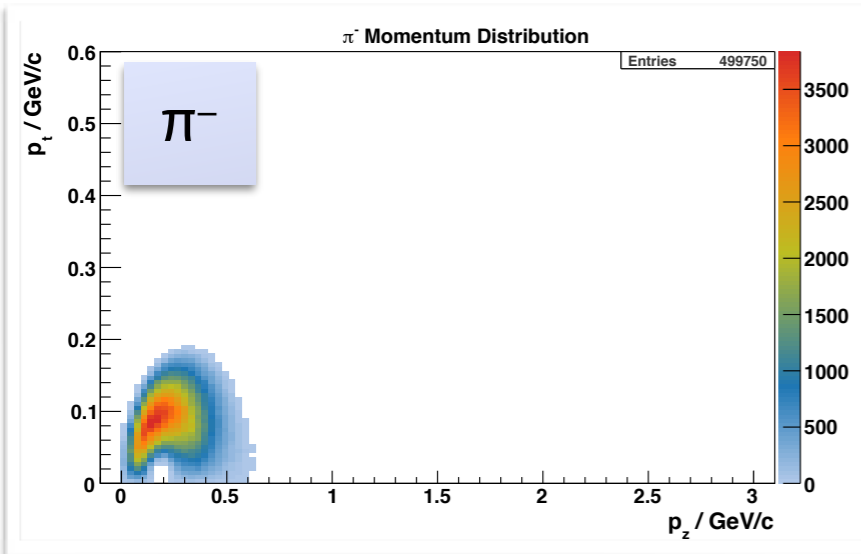
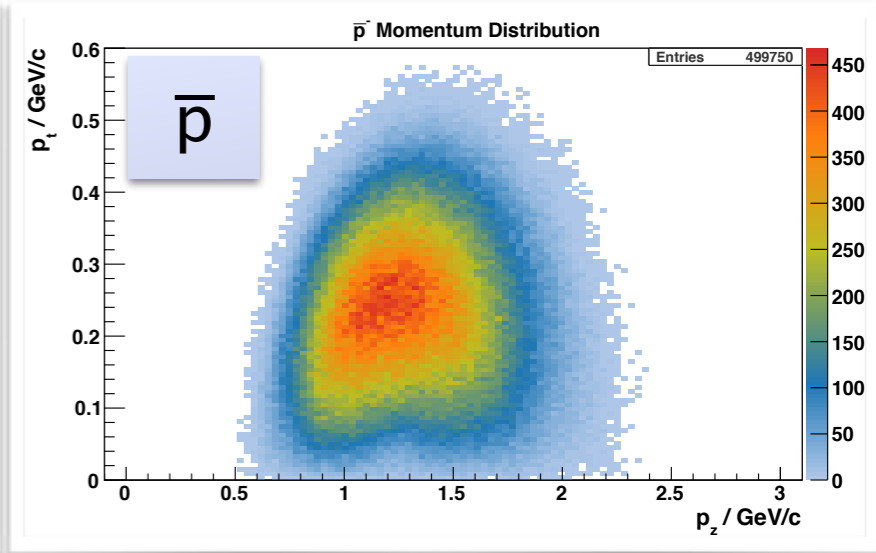
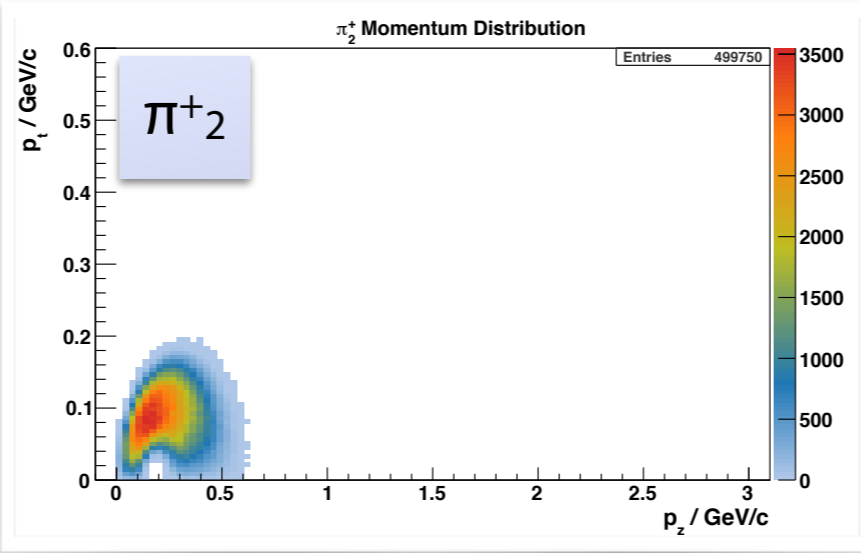
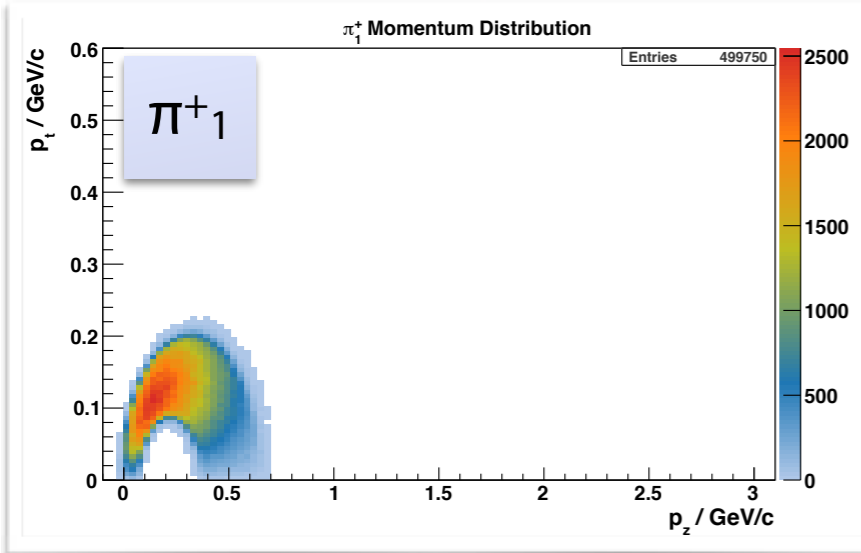
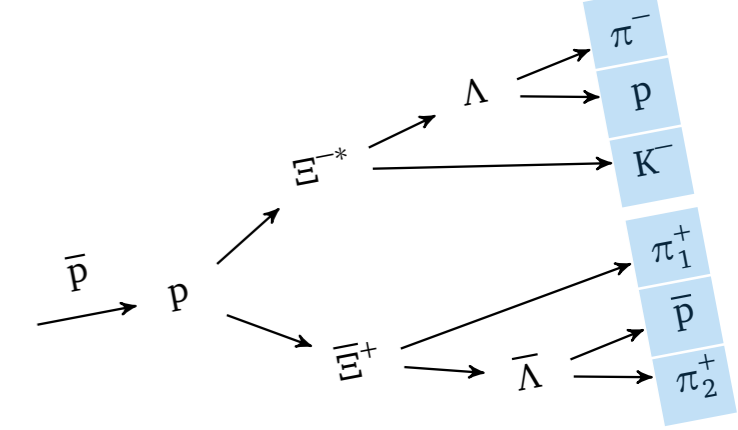
EvtGen — Momentum Distributions



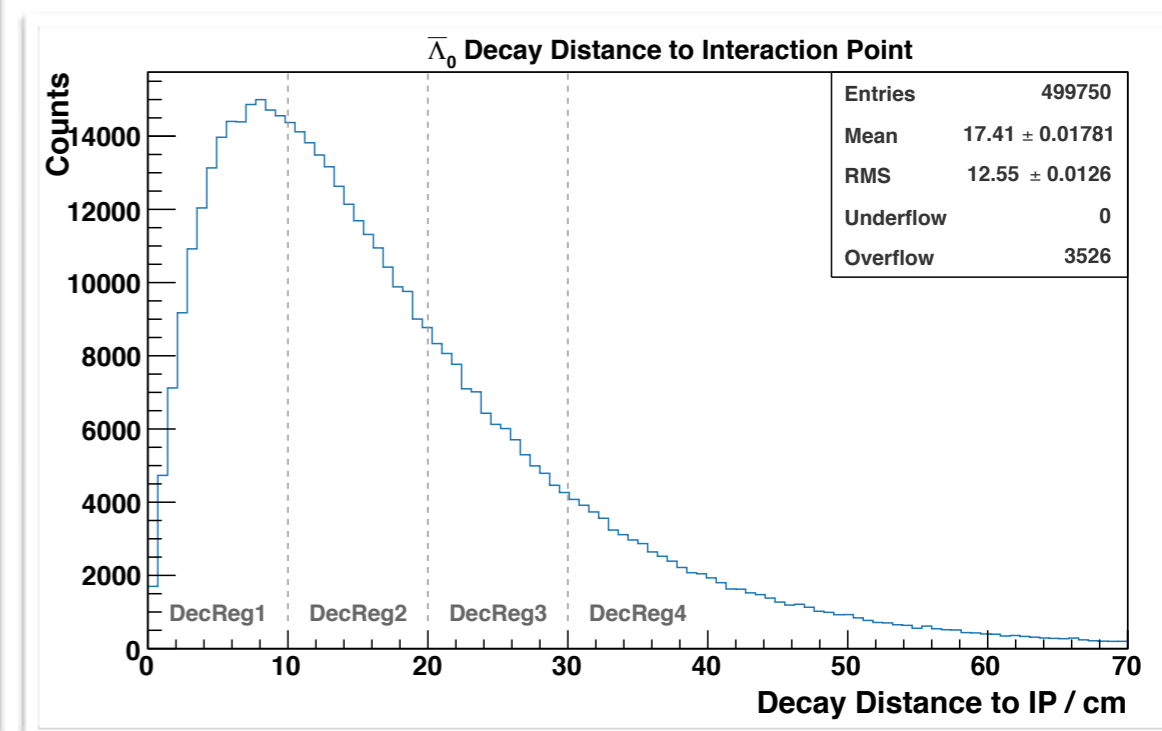
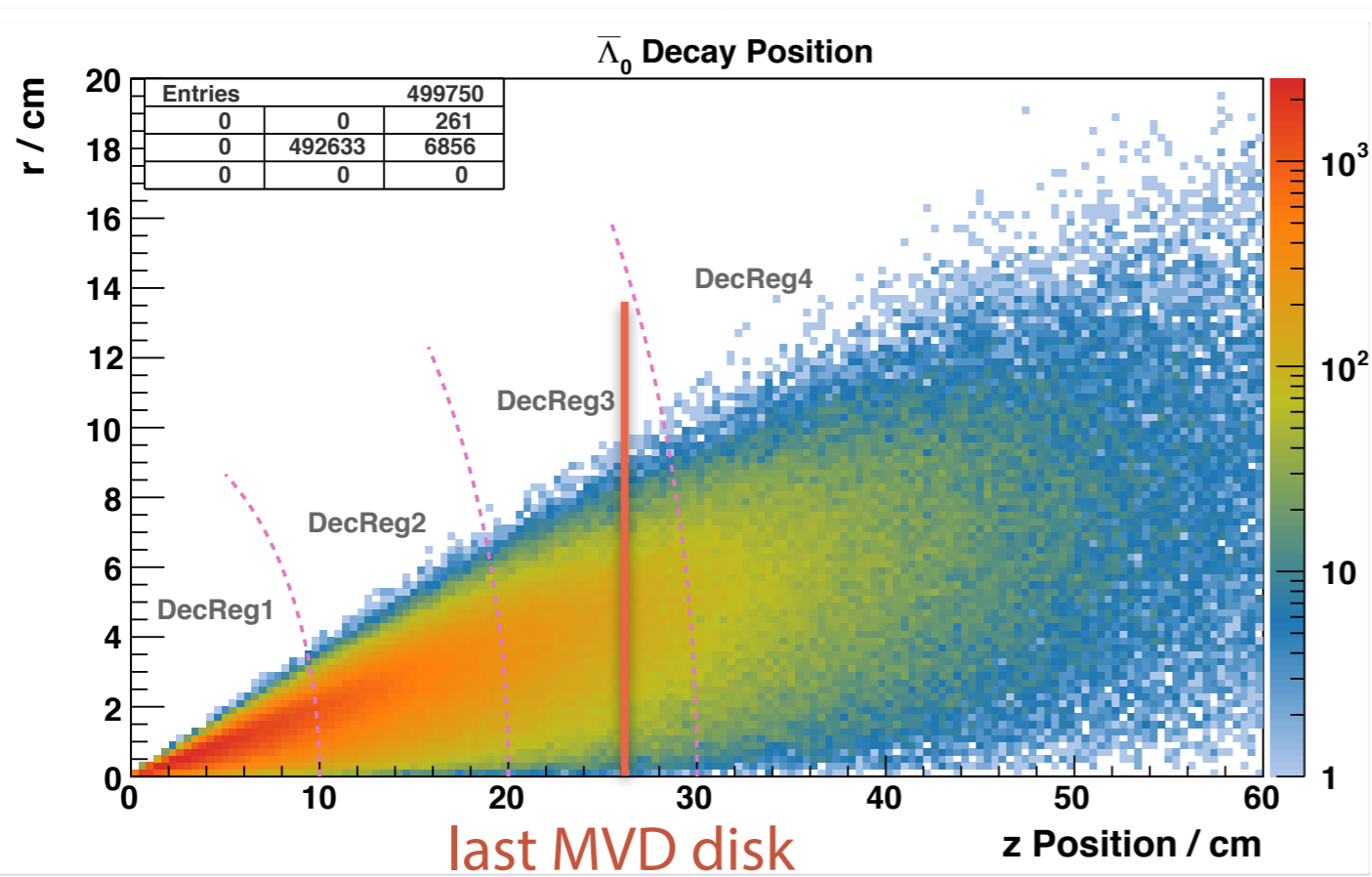
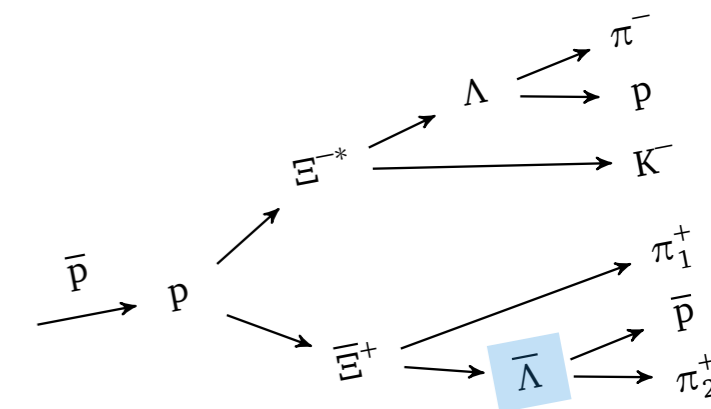
Simulated
499,750 events

Phase space
production

EvtGen — Final State Particles



EvtGen — Λ Decay Vertex

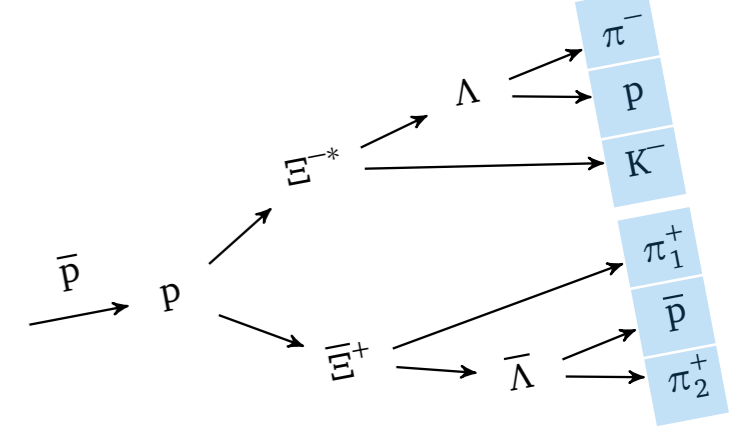
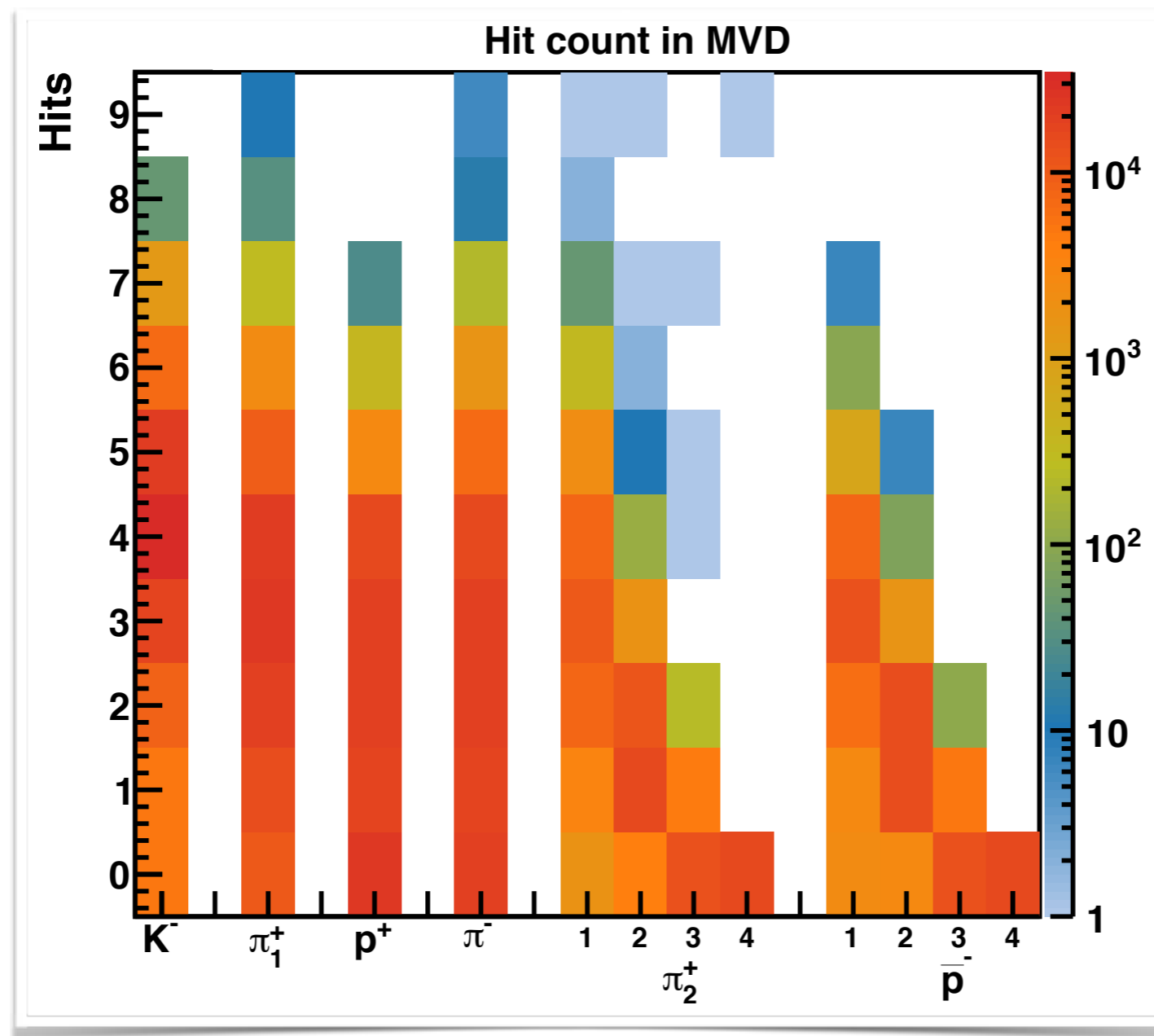


- $\bar{\Lambda}$ decay vertex: $O(10 \text{ cm})$
 - Significant part (26 %) outside of MVD

$\bar{\Lambda}$ decay regions:

- 1: 0-10 cm
- 2: 10-20 cm
- 3: 20-30 cm
- 4: 30-40 cm

Detector Response — Hit Counts



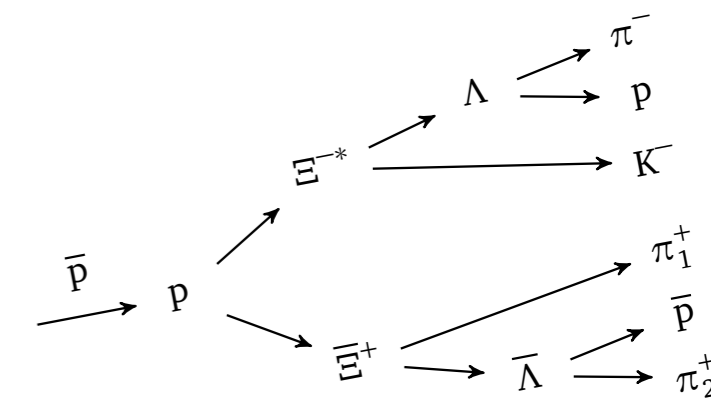
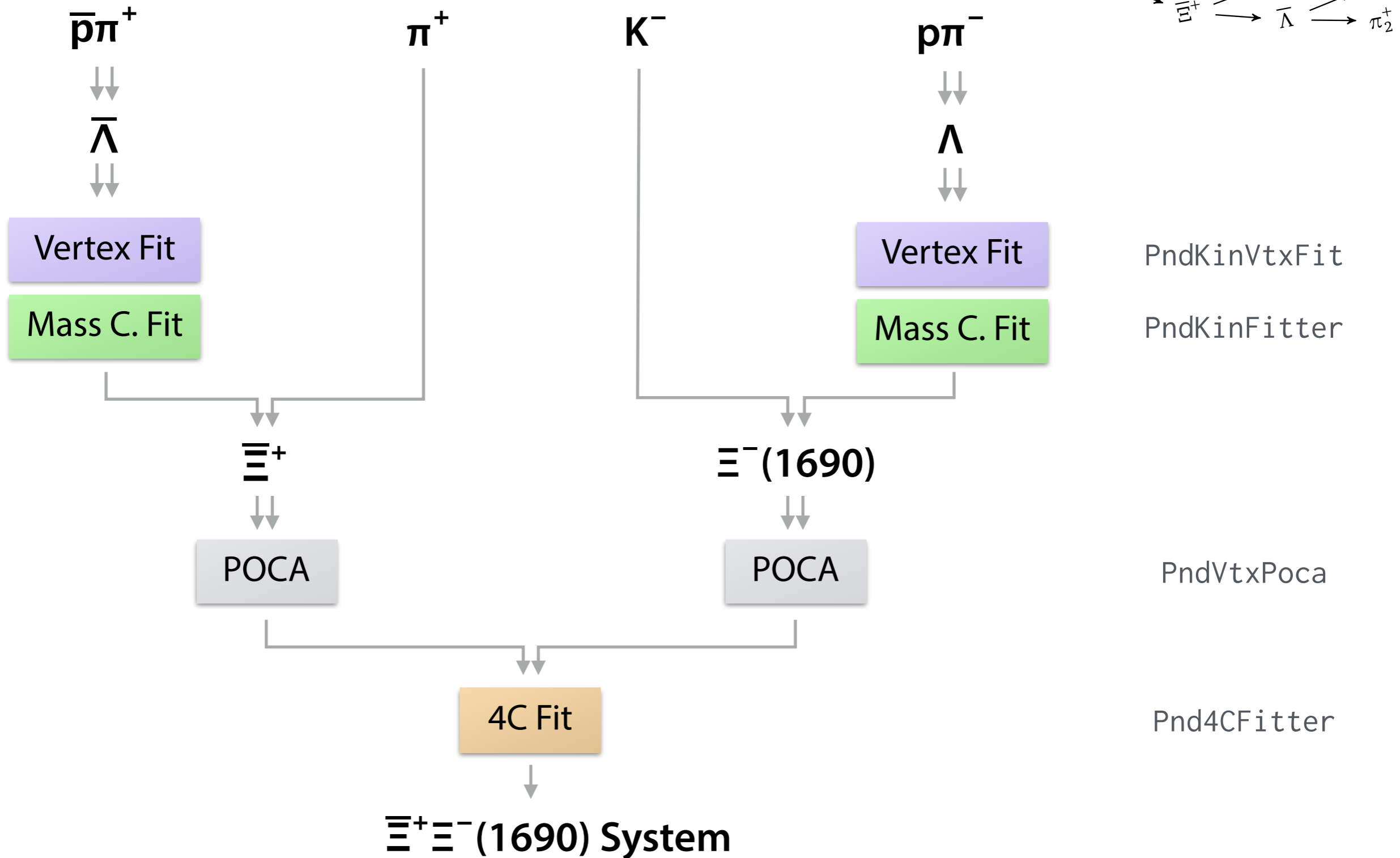
$\bar{\Lambda}$ decay regions:

- 1: 0-10 cm
- 2: 10-20 cm
- 3: 20-30 cm
- 4: 30-40 cm

- Hit counts of final state particles in MVD
 - Fraction of $\bar{\Lambda}$ daughters need other detectors for vertexing

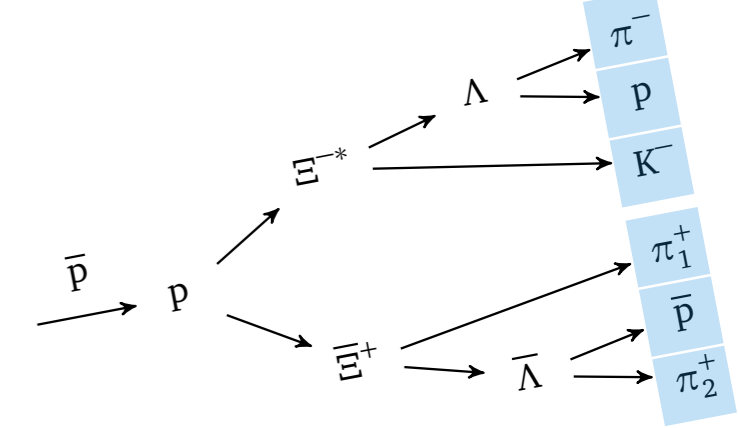
RECONSTRUCTION

Reconstruction Strategy



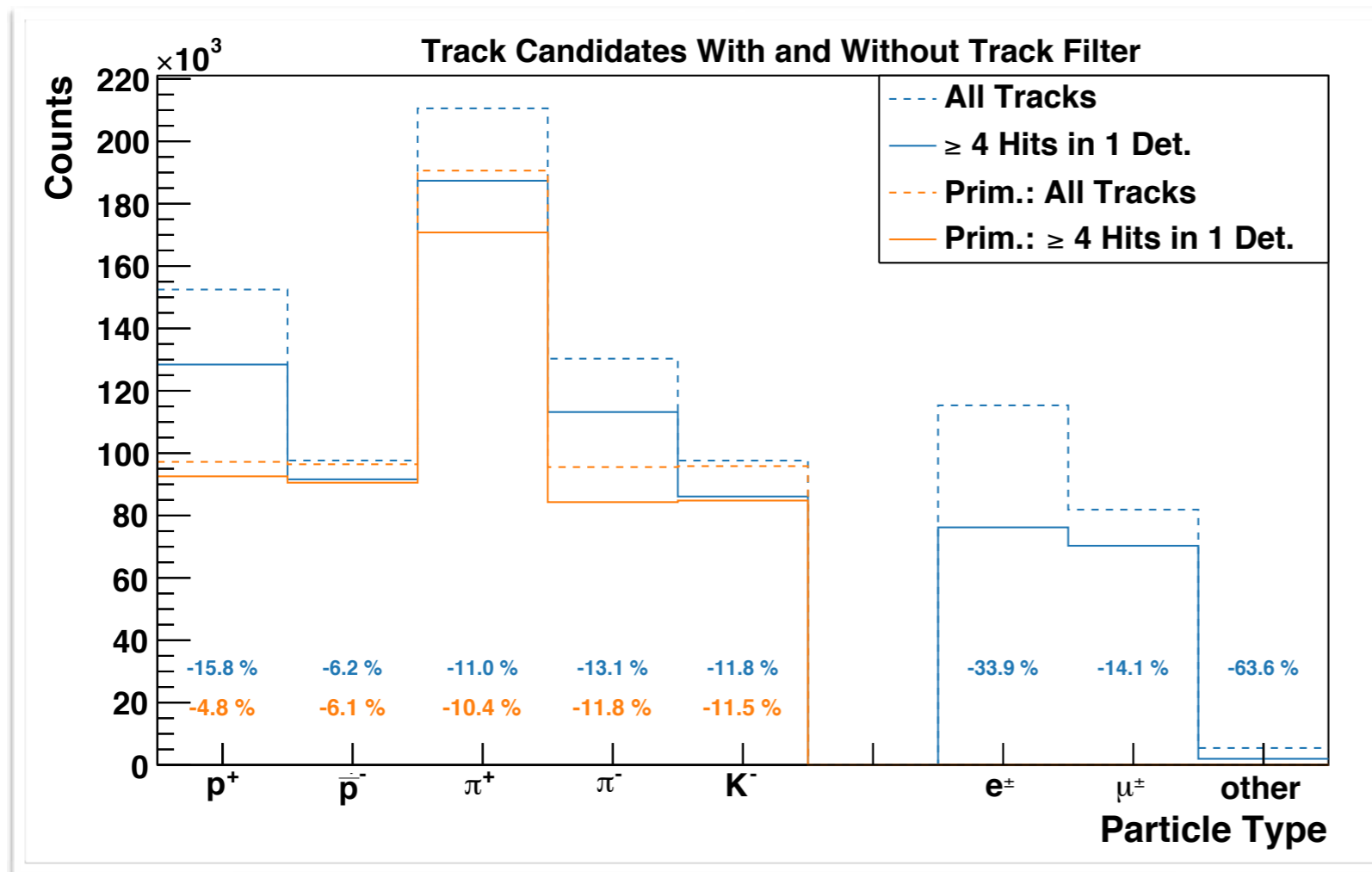
Track Filter in Reconstruction

- Track finding algorithms not yet ready for displaced vertices \Rightarrow **ideal track finding**
 - Finds every track with ≥ 1 hit
 - Unreasonable for realistic tracking
 - 3 hits for line (r-z), 4 hits for circle (x-y)
- Filter: Min. 4 hits in any tracking detector



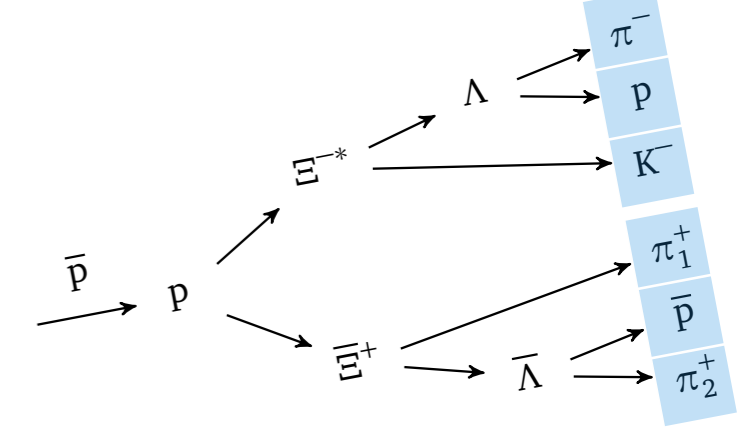
Examples:

MVD	3	MVD	5	MVD	3
STT	0	STT	9	STT	0
GEM	2	GEM	6	GEM	0
FTS	0	FTS	0	FTS	40



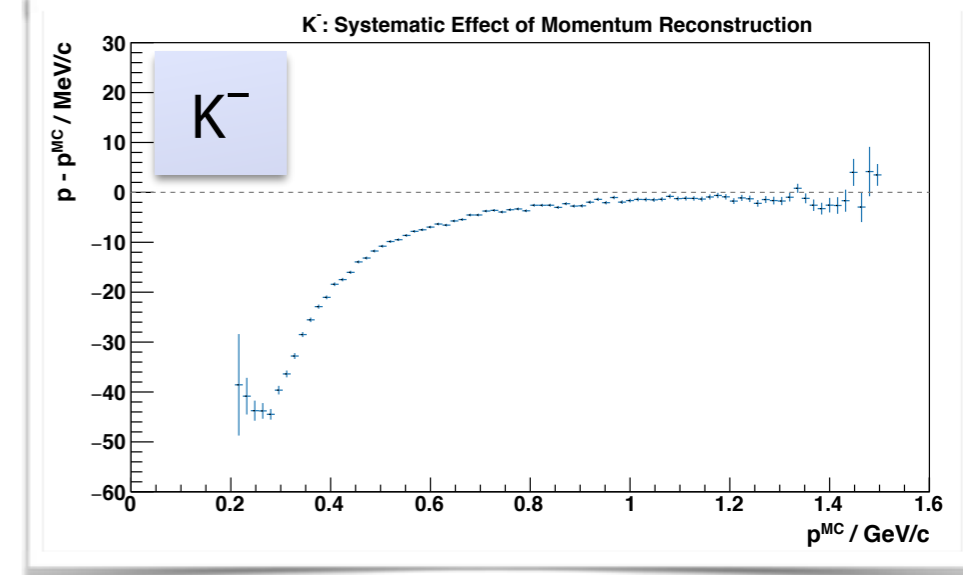
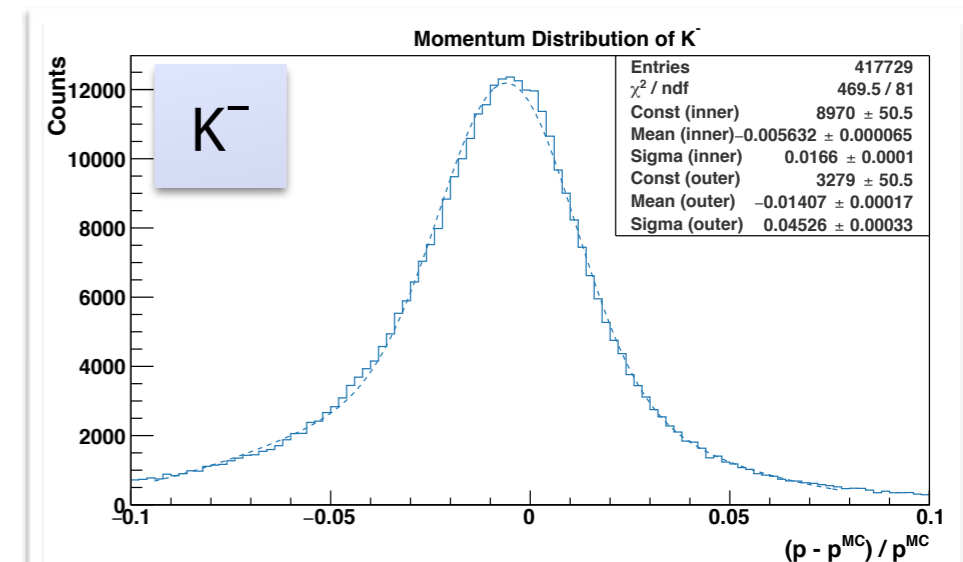
Final State Particle Efficiency

- Full reconstruction chain with PandaRoot (digitization, reconstruction, particle id.)
 - Ideal particle identification
- Reconstructability of final state particles



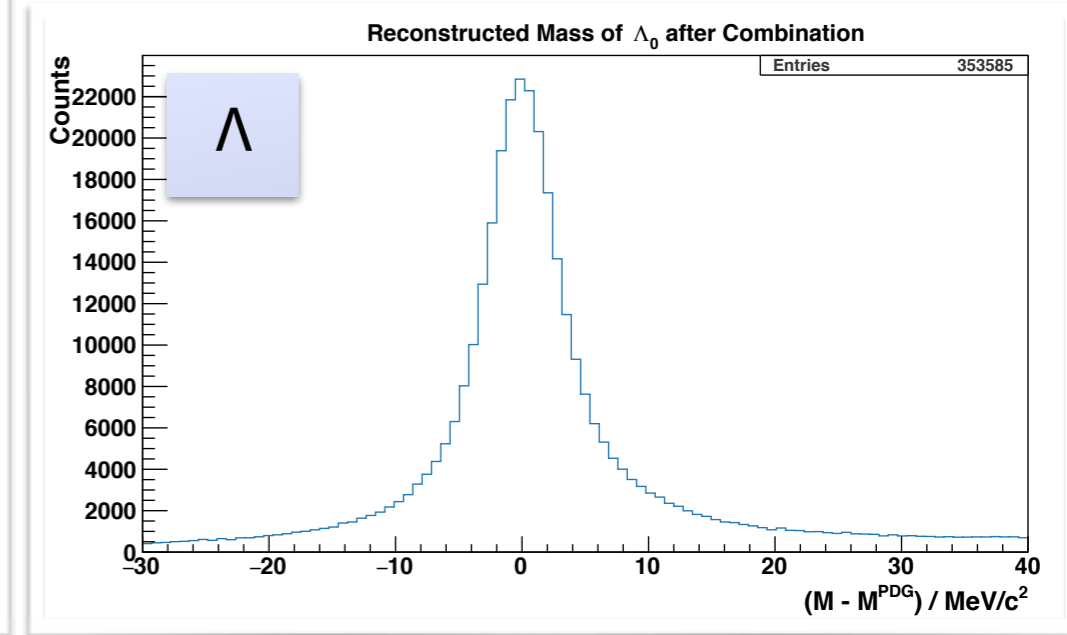
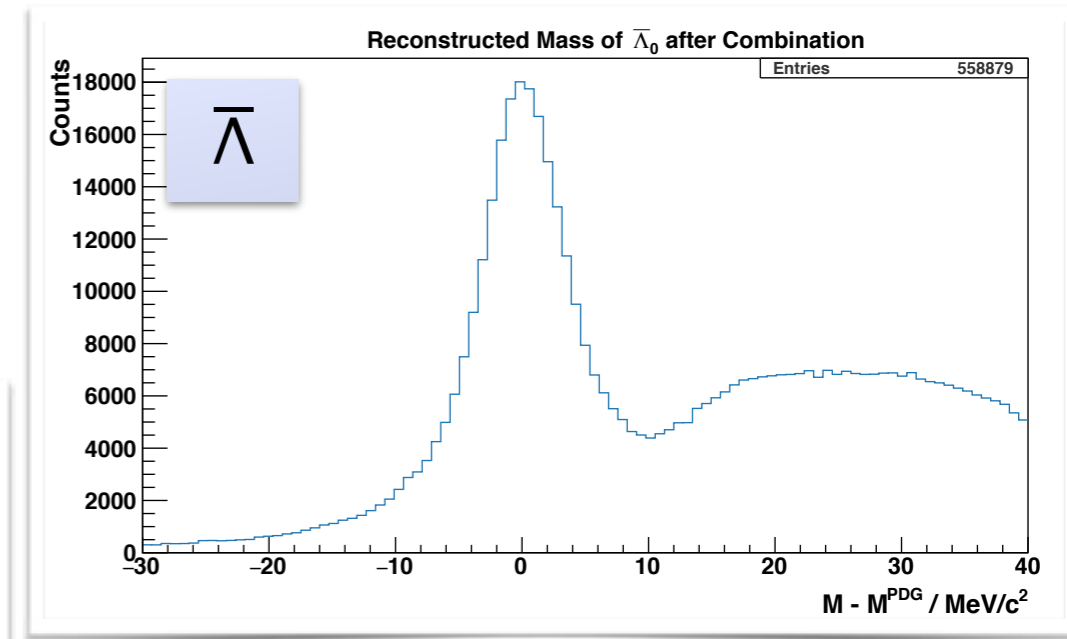
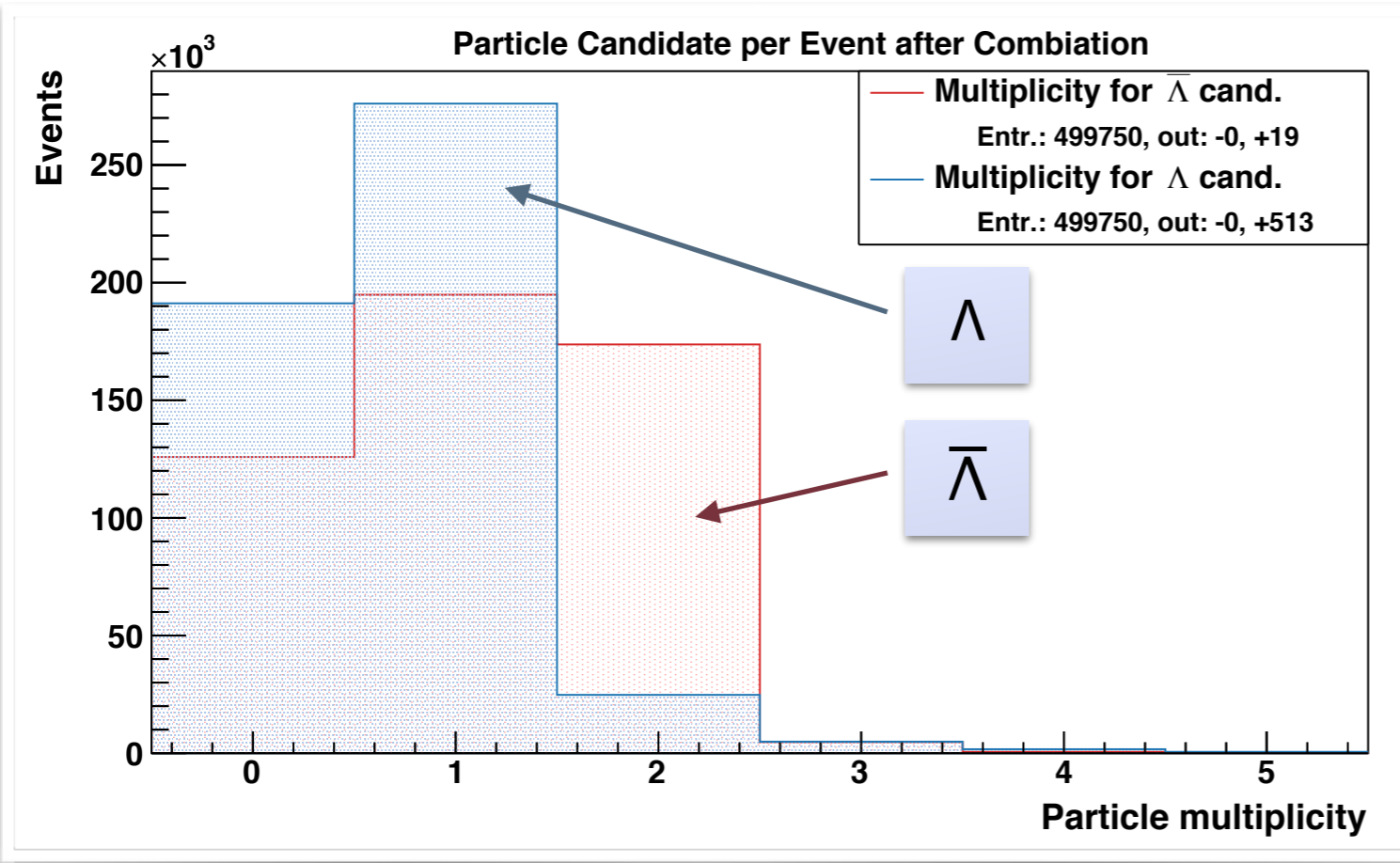
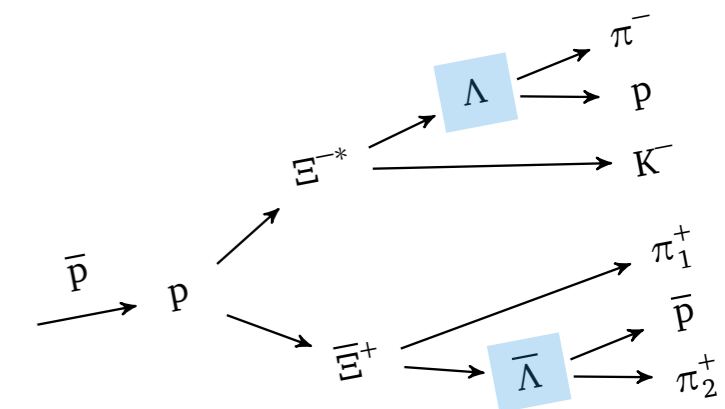
Mother Particles	$\Xi^- (1690)$			Ξ^+		
	Λ	Λ	Λ	$\bar{\Lambda}$	$\bar{\Lambda}$	$\bar{\Lambda}$
Final States	π^-	p	K^-	π^+_2	\bar{p}	π^+_1
N / %	67.1	90.7	83.6	64.6	85.4	68.1
σ_p/p / %	1.43	1.49	1.66	1.44	1.47	1.35

- π with very low momenta (few 100 MeV/c)
 - (anti-)protons high longitudinal momenta
- Probability to find all: $\sim 19\%$

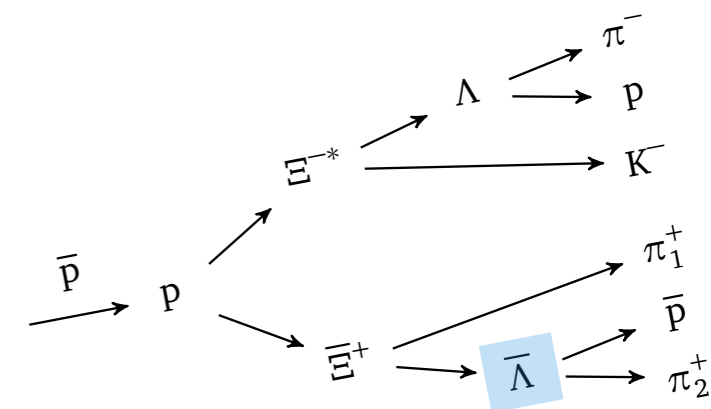


$\Lambda\bar{\Lambda}$ Combination

- Combining of $\pi p \rightarrow \Lambda$
- For $\bar{\Lambda}$: second π^+ in final state
 - Combinatorial background

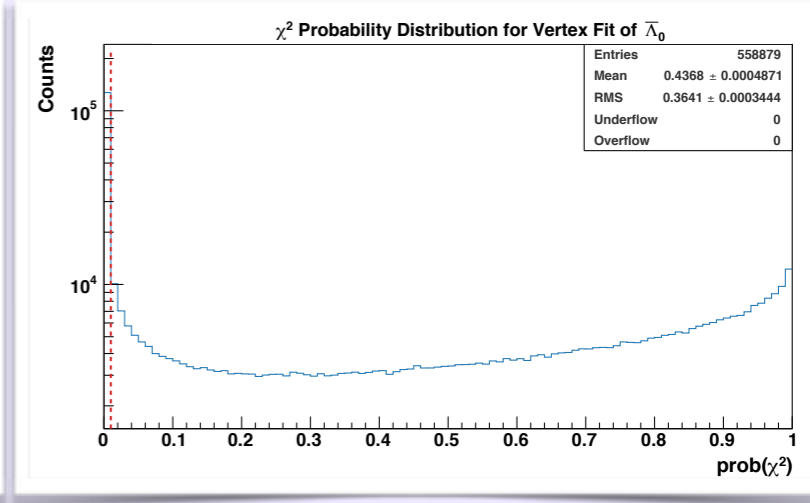
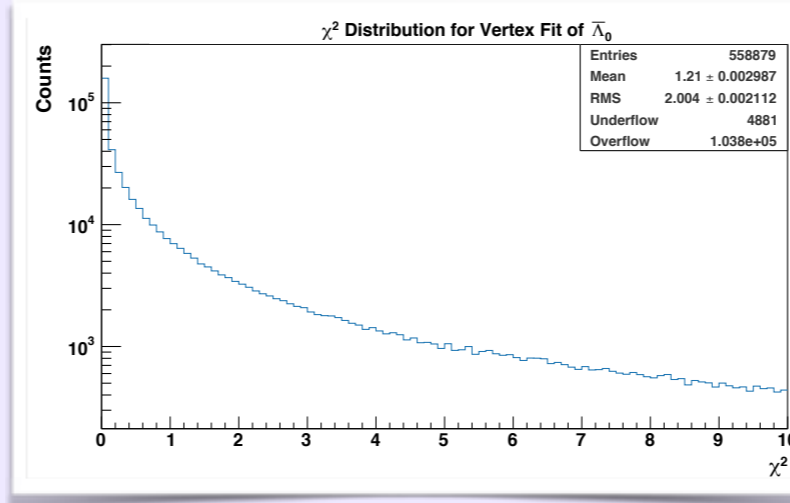


$\bar{\Lambda}$ Vertex Reconstruction



Vertex Fit

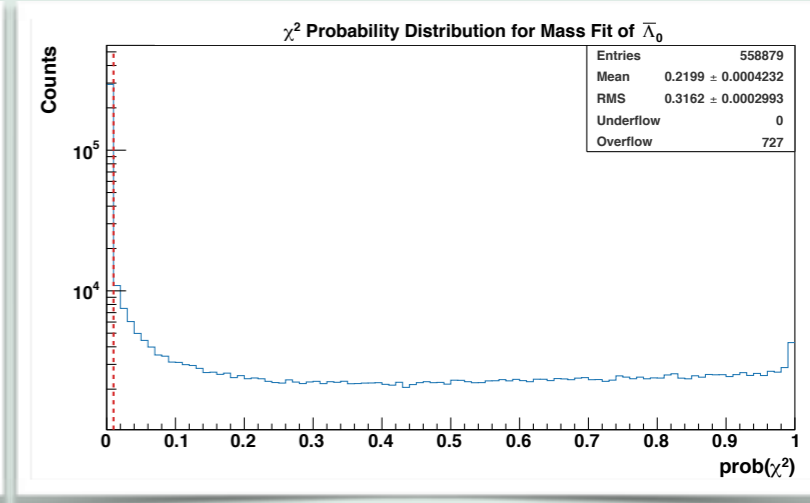
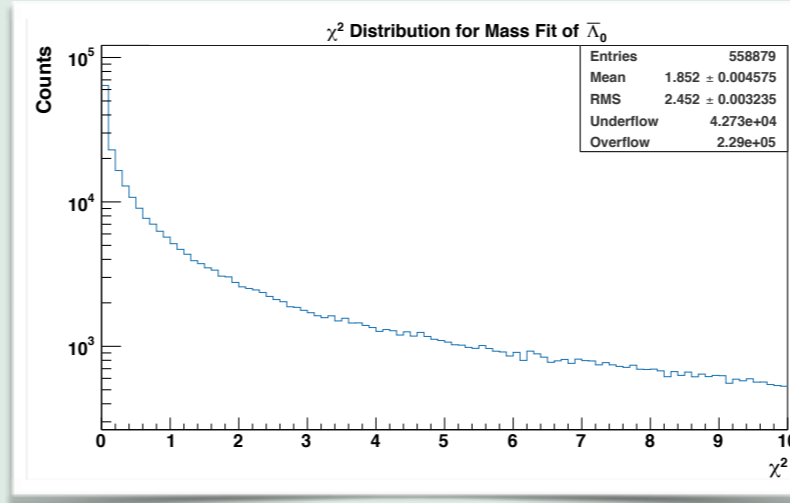
- Daughters constraint to one common point
- Best candidate:
 - prob. > 0.01
 - lowest χ^2



Σ : 559k \rightarrow 324k (- 42 %)

Mass Fit

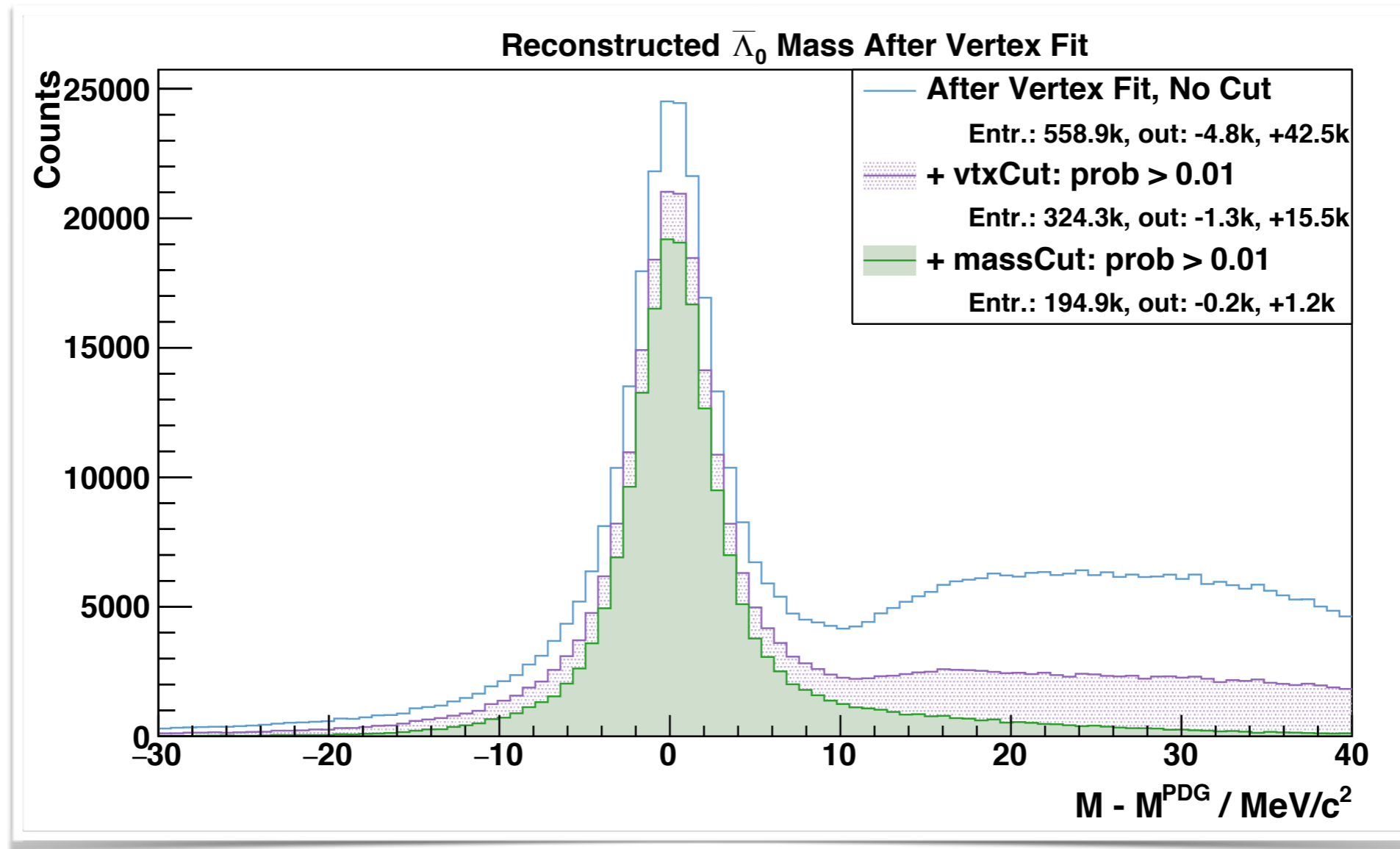
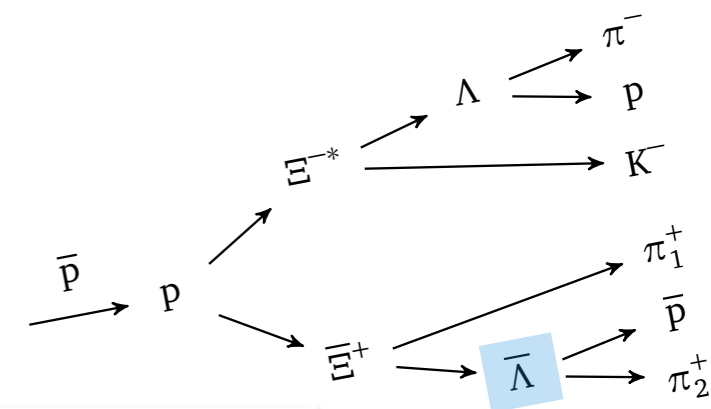
- System constraint to given mass
- Best candidate:
 - prob. > 0.01
 - lowest χ^2



Σ : 324k \rightarrow 195k (- 40 %)

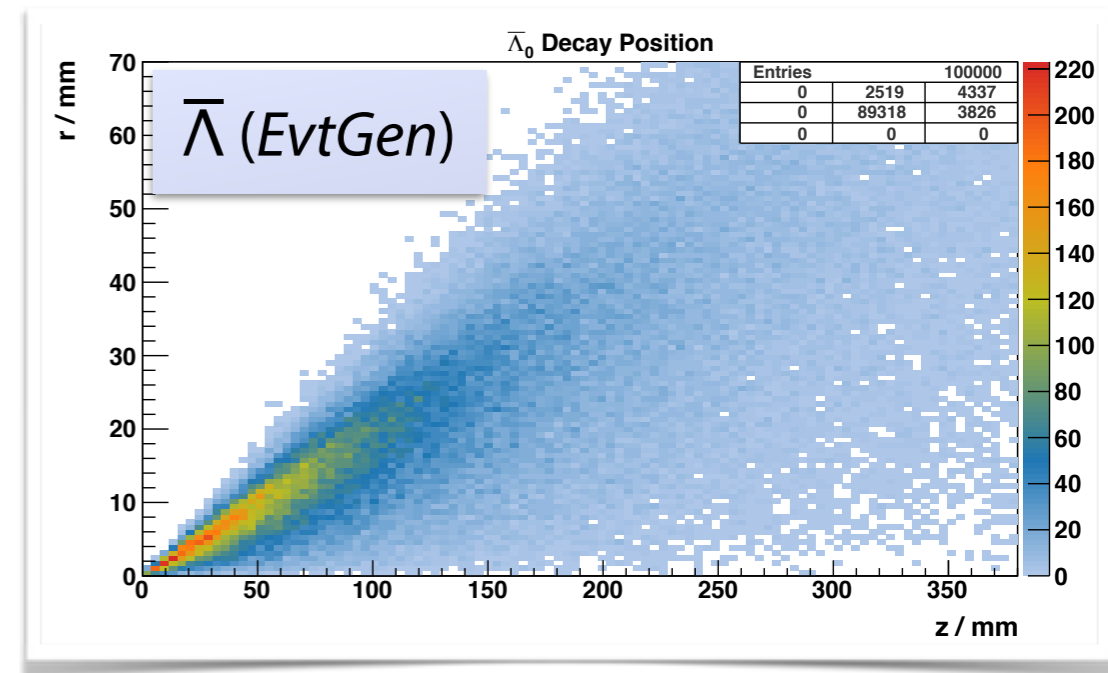
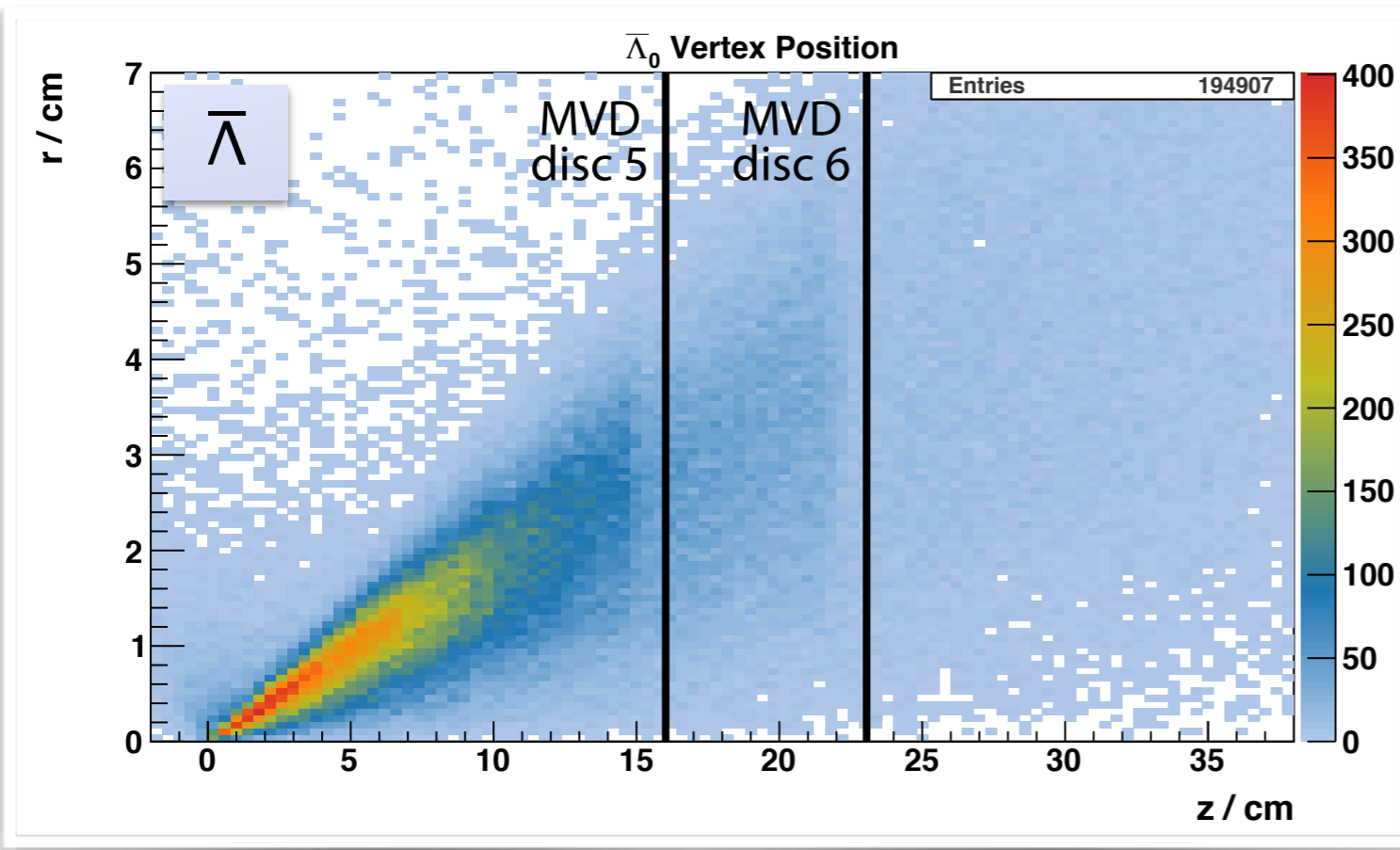
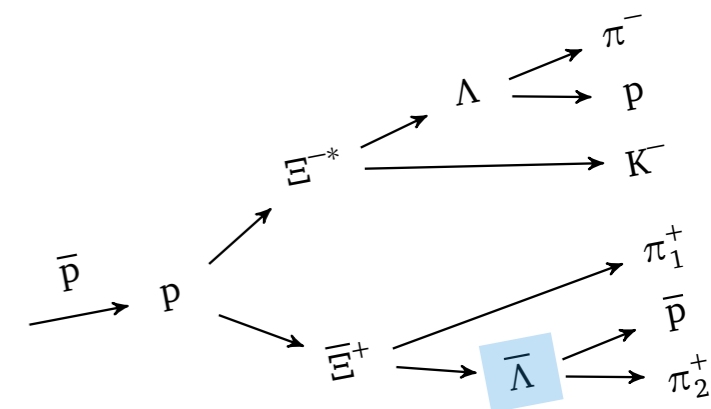
Simulated events: 499,750

$\bar{\Lambda}$ Invariant Mass



⇒ Good suppression of wrong combinations

$\bar{\Lambda}$ Vertex & Momentum Resolutions



Vertex resolution:

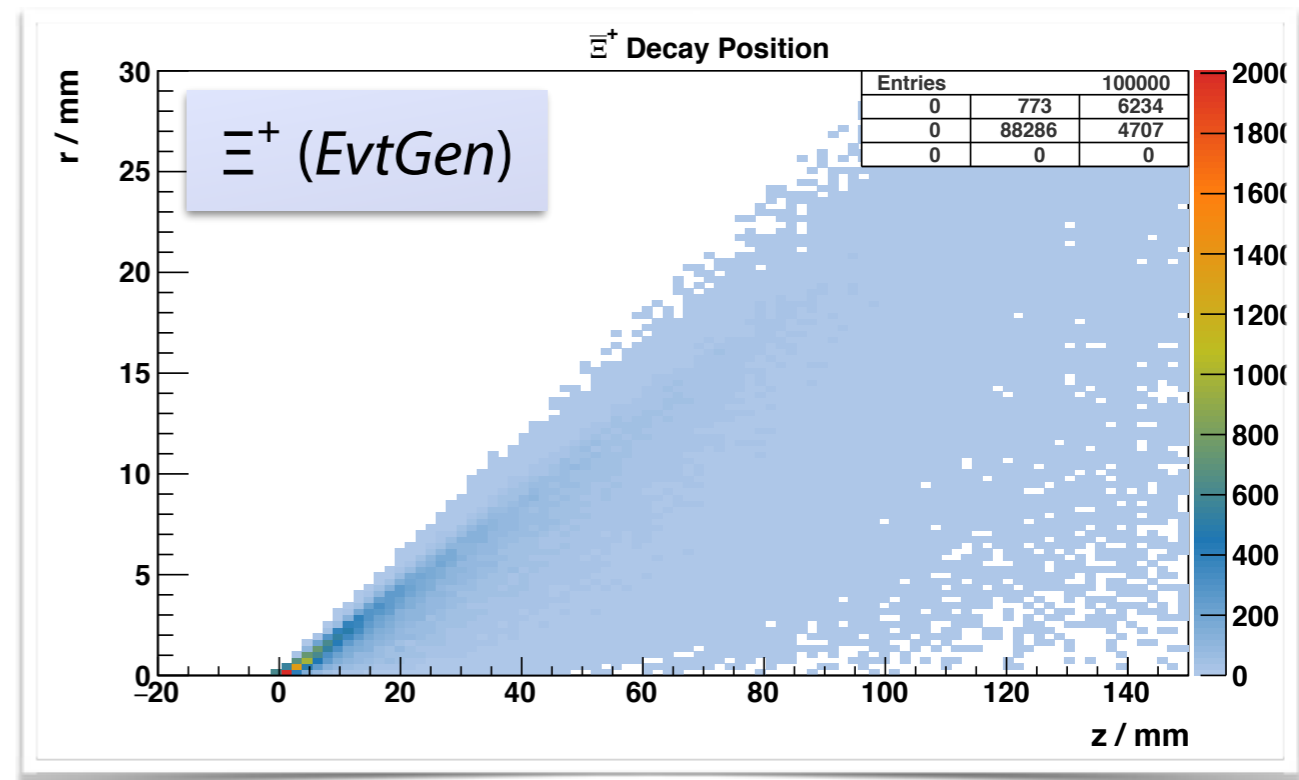
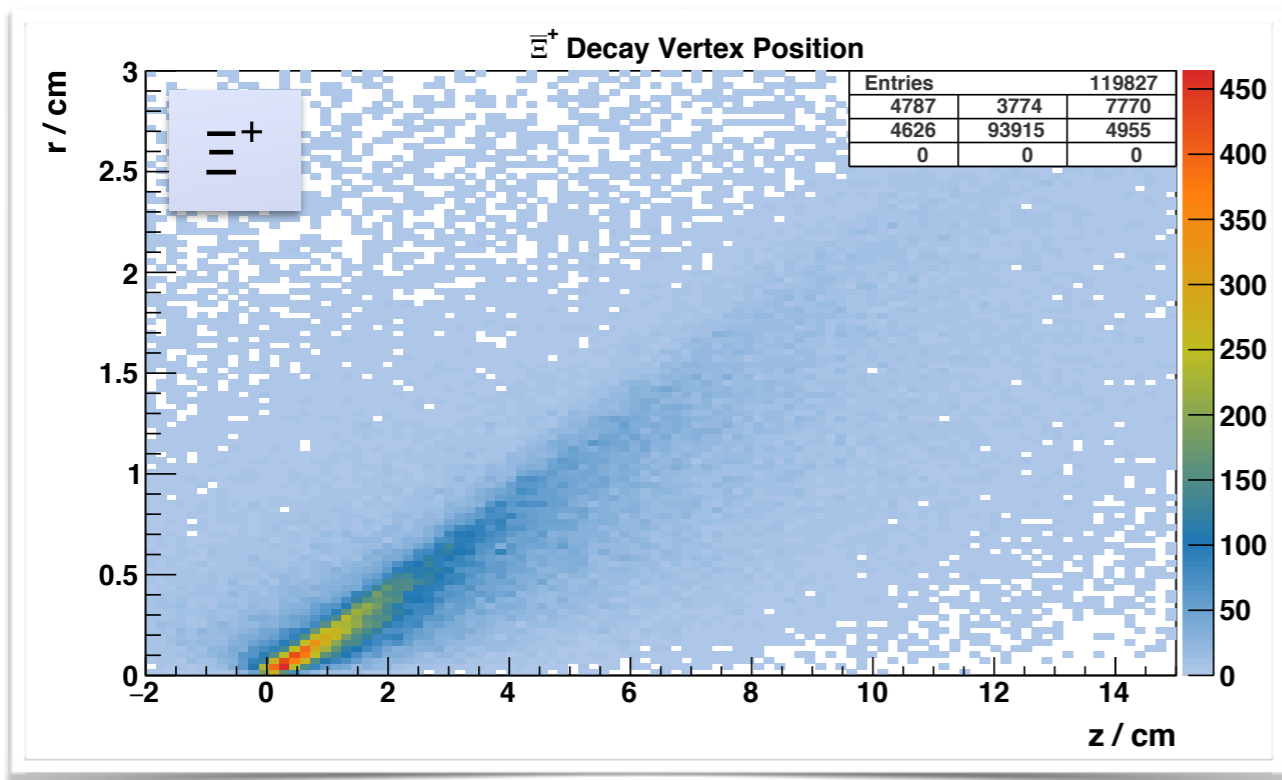
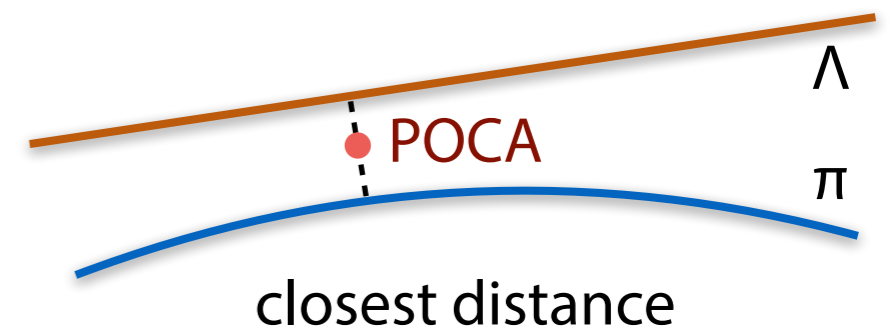
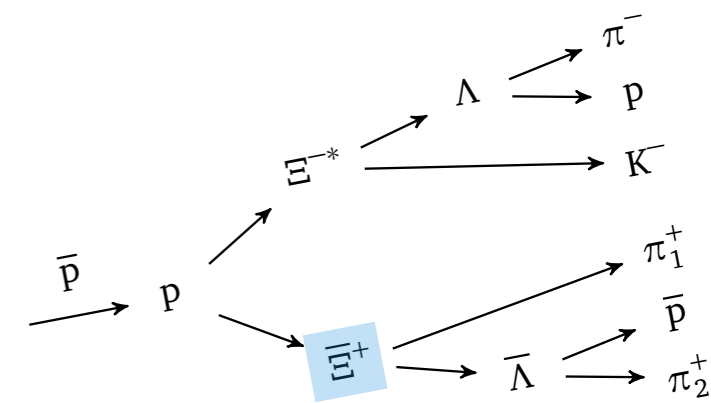
Direction	σ_{vtx} / mm		
	after fits	+ cuts	+ MVD
x	1.07	0.99	0.56
y	1.05	0.96	0.56
z	5.77	5.42	3.29
Σ (MC match)	57k	37k	22k

Momentum resolution:

Direction	$\sigma_p/p / \%$		
	after fits	+ cuts	+ MVD
p_t	7.54	6.67	5.91
p_z	4.42	3.50	3.05

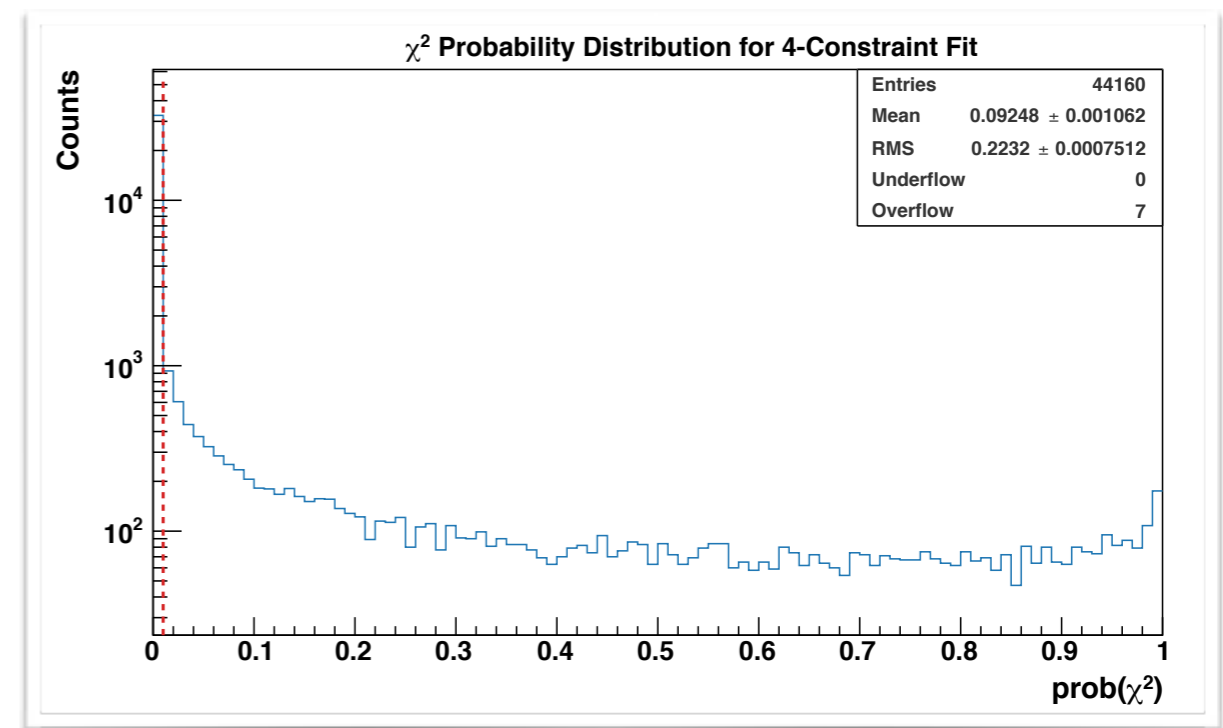
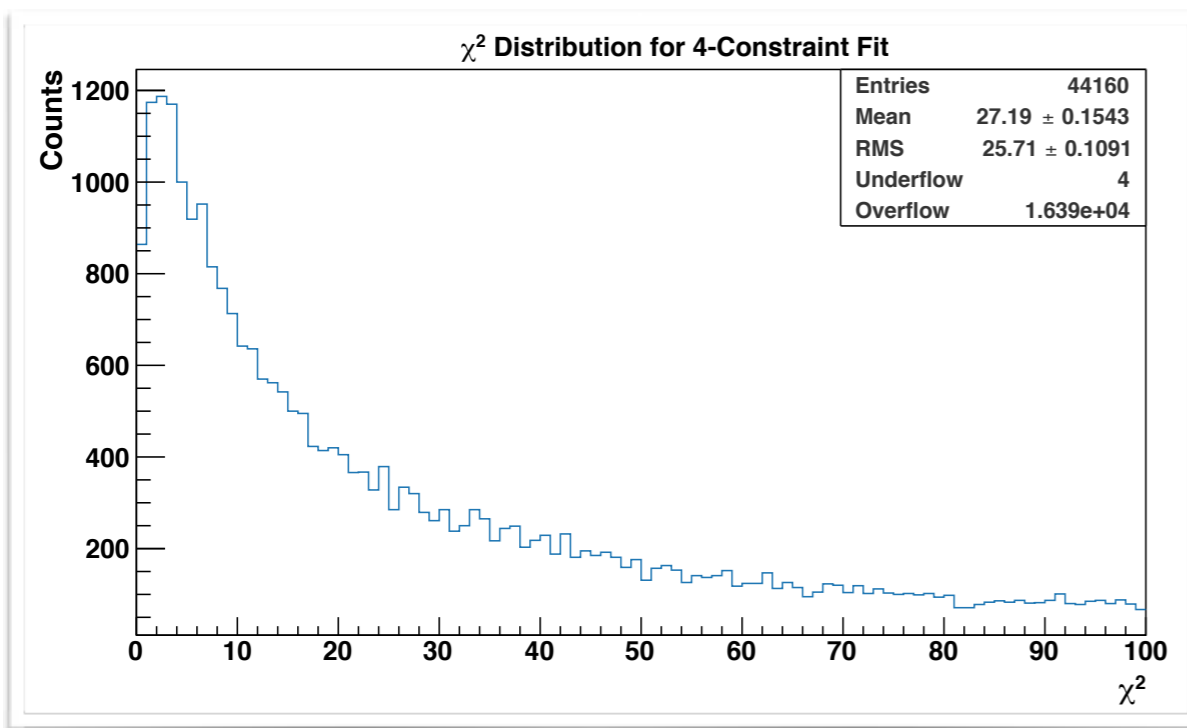
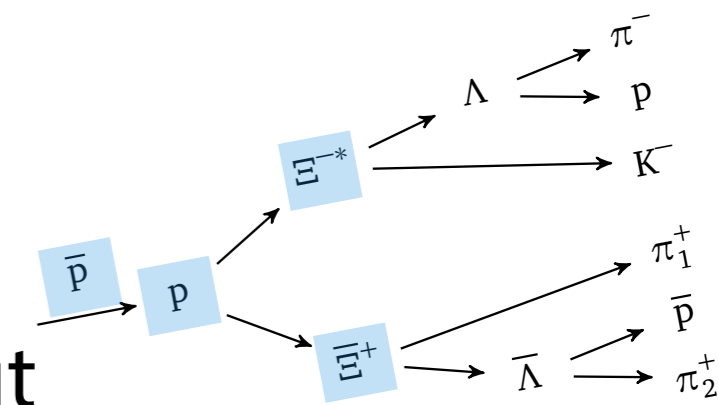
Ξ^+ Reconstruction

- Status of PandaRoot for this analysis:
Vertex fitting not possible for neutral daughter(s)
 - In the meantime: fix developed by J. Pütz
- Alternative:
Point of closest approach (POCA)
 - Calculated, no *fitting*

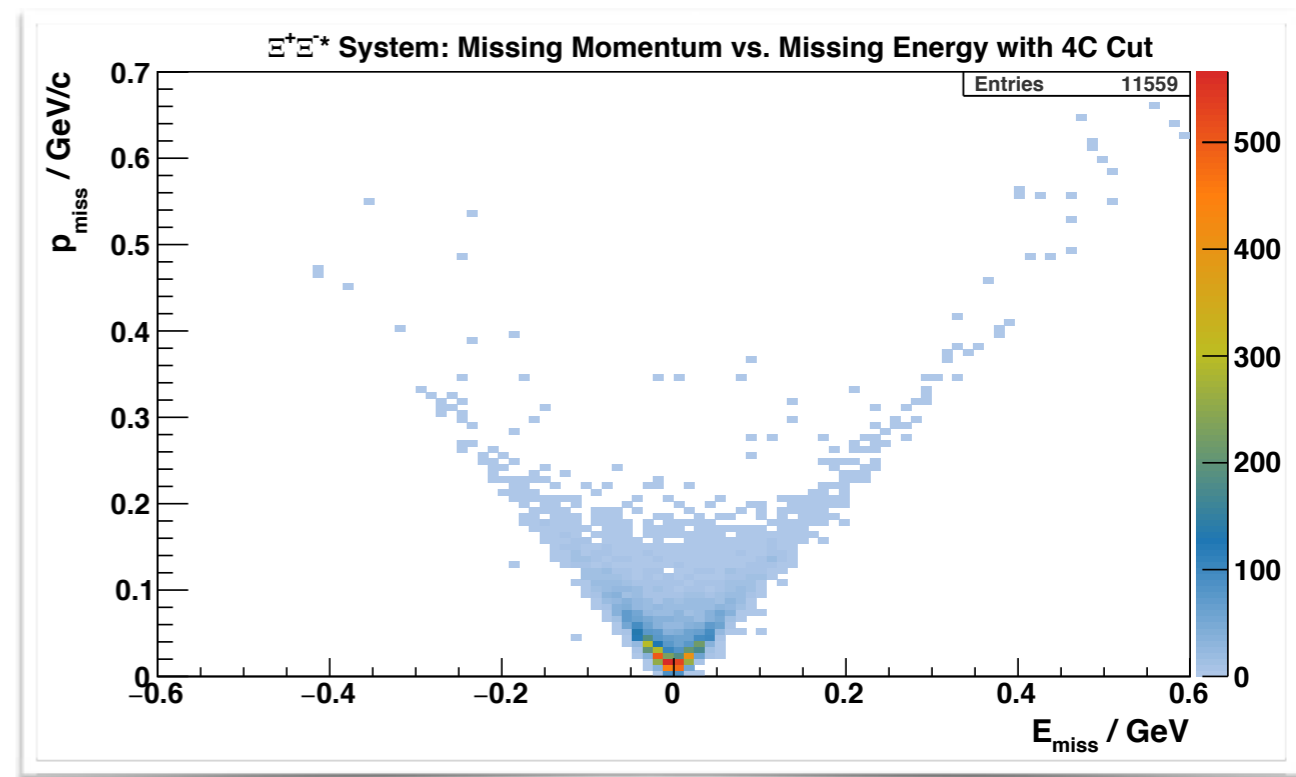
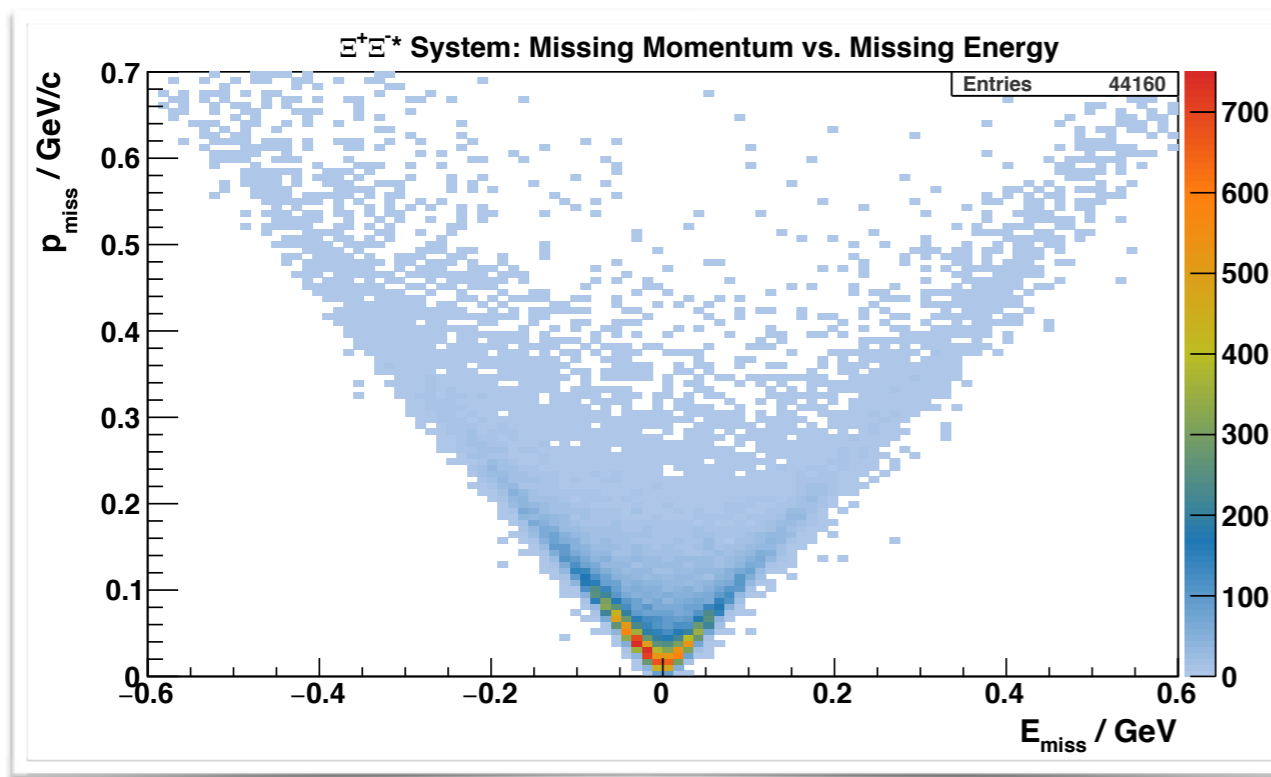
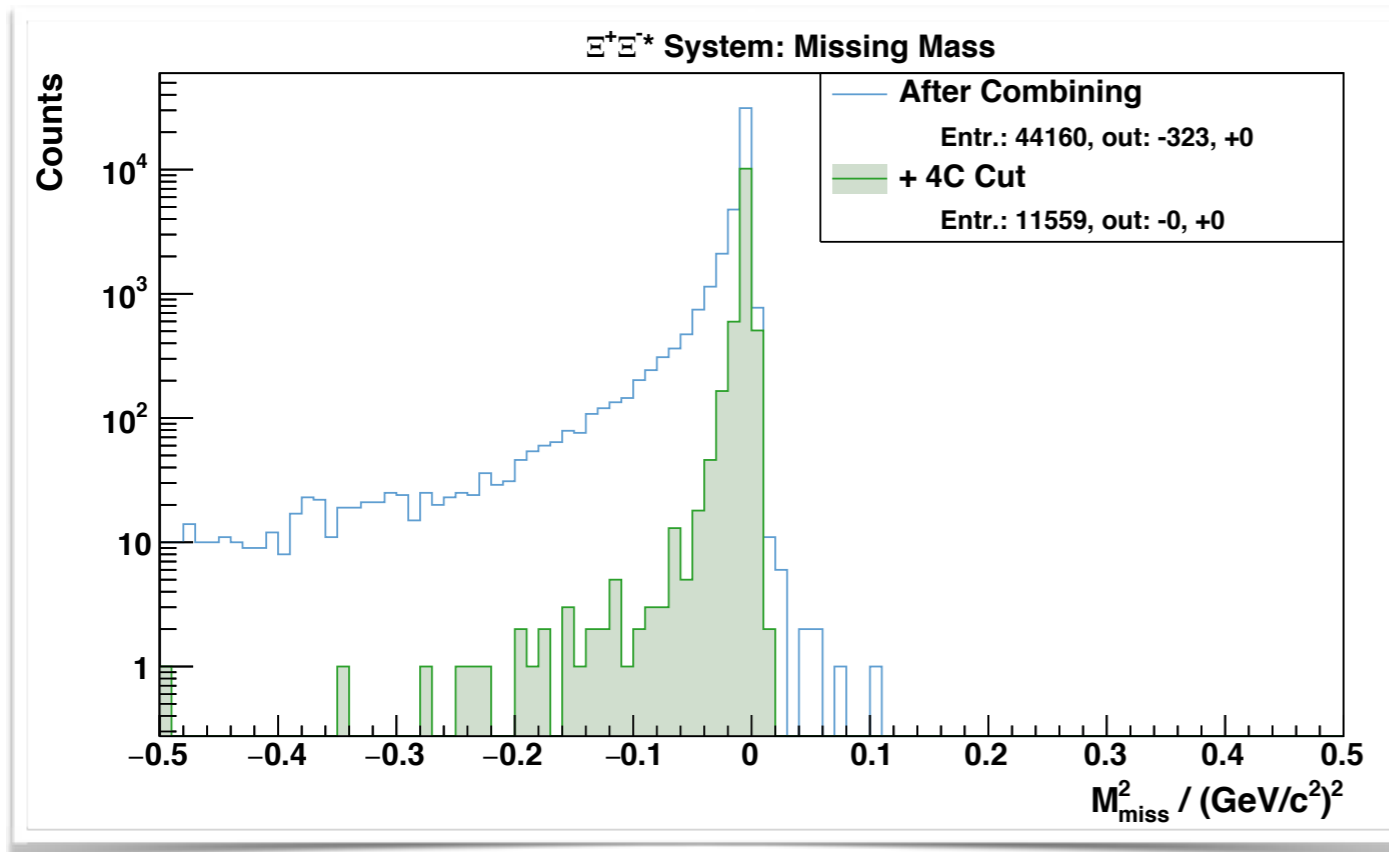
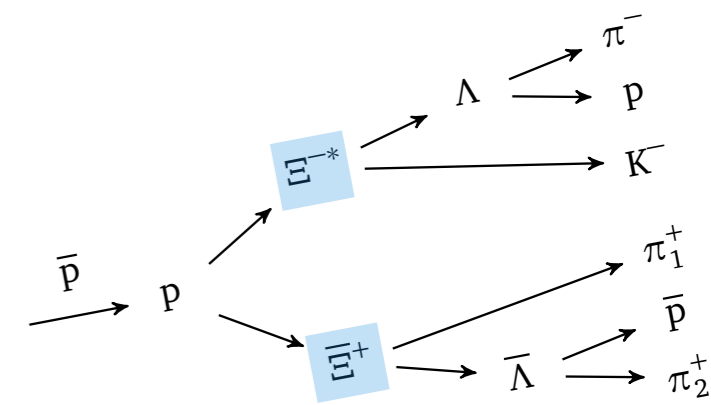


$\Xi^+ \Xi^-$ System Reconstruction

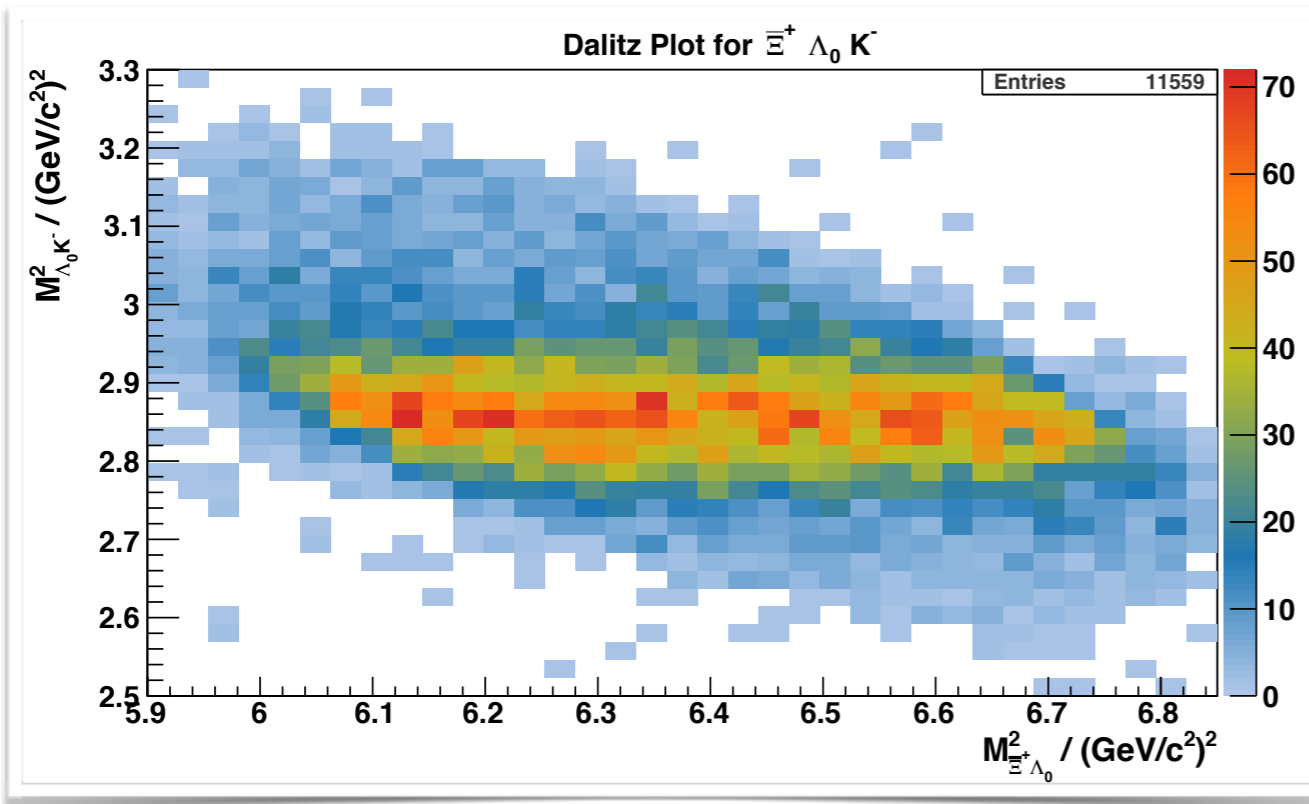
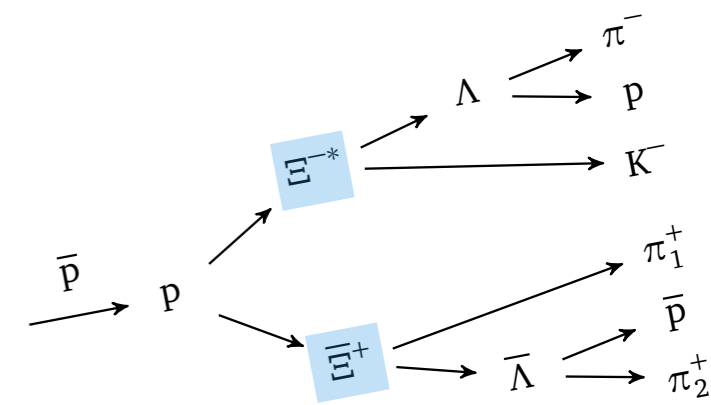
- Exclusive reconstruction with four-constraint fit
 - Adjusts daughters to fit beam-target system
- Remove candidates with $\text{Prob}(\chi^2) < 0.01$
- Out of 499,750 events: **11,427 (2.3 %)** survive



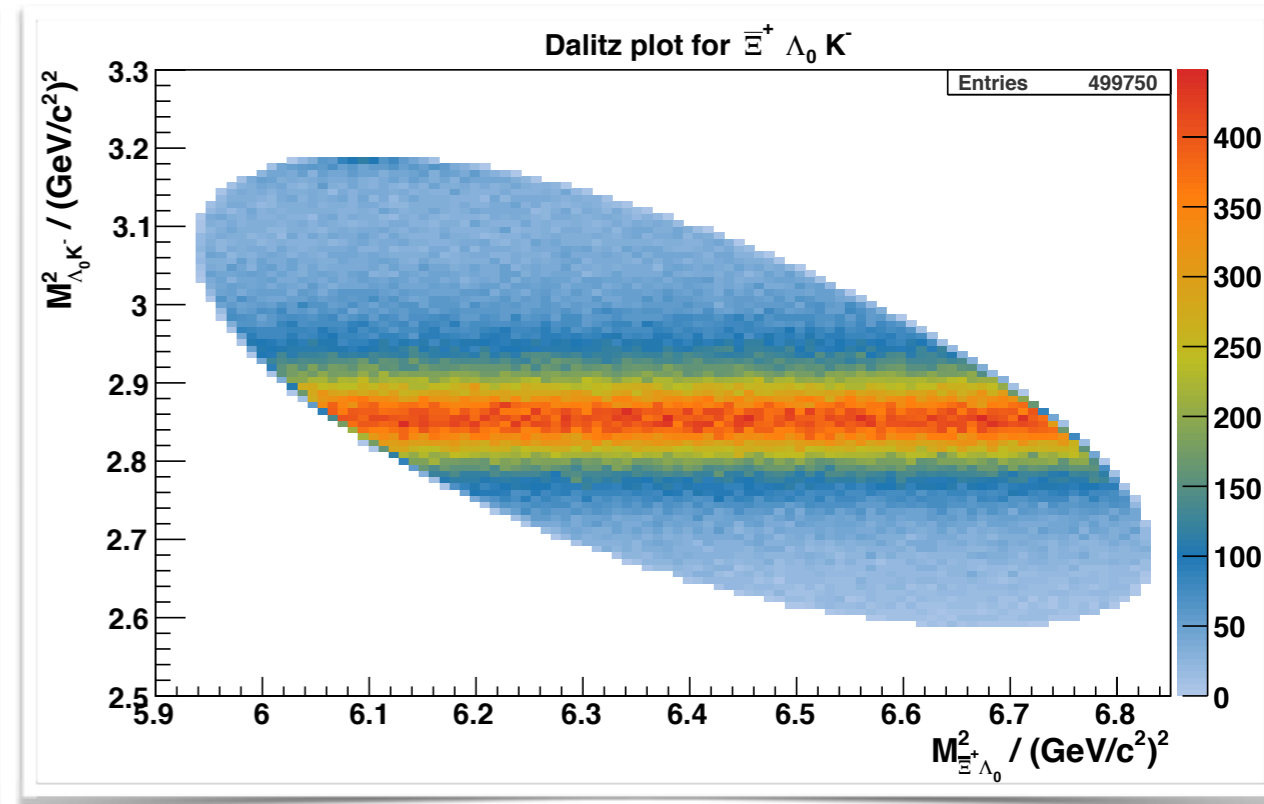
$\Xi^+ \Xi^-$ System — Missing Mass & E vs. p



$\Xi^+ \Xi^-$ System — Dalitz-Plot



Reconstructed



Simulation input

$\Xi^+ \Xi^-$ System — Overview

	$\Xi^-(1690)$				Ξ^+			
	N %	σ_{p_t}/P_t %	σ_{p_z}/P_z %	σ_M MeV/c ²	N %	σ_{p_t}/P_t %	σ_{p_z}/P_z %	σ_M MeV/c ²
<i>Inclusive</i>								
Combination	37.5	3.06	1.62	3.67	24.0	2.92	1.55	3.17
Include MVD	28.3	2.98	1.64	3.58	15.3	2.83	1.58	3.07
<i>Exclusive</i>								
Combination	8.8	3.04	1.61	3.65	8.8	2.94	1.57	3.17
4C Cut	2.3	2.75	1.23	3.29	2.3	2.50	1.16	2.88

Exclusive efficiency: **2.3 %**

(with conservative cuts)

BACKGROUND

Signal Significance Optimizations

Background Studies

- So far: **only conservative cuts** ($P > 0.01$)
 - Optimize those and other cuts for good background suppression
- Background simulated with DPM

- $\sim 47 \times 10^6$ background events

- Cross sections:

$$\sigma_{\text{bkg}} \approx 50 \text{ mb}, \quad \sigma_{\text{sig}} \approx 1 \mu\text{b}$$

- Combined branching ratios:

$$\text{BR}_{\text{sig}} = 40.8 \%$$

Branching ratios for the particle decays used

Particle	Decay Daughters	Branching Ratio
$\bar{\Xi}^+$	$\bar{\Lambda} \pi^+$	$(99.887 \pm 0.035) \%$
$\bar{\Lambda}$	$\bar{p} \pi^+$	$(63.9 \pm 0.5) \%$
$\Xi^-(1690)$	ΛK^-	<i>seen</i>
Λ	$p \pi^-$	$(63.9 \pm 0.5) \%$

- Optimization based on **significance ratio**

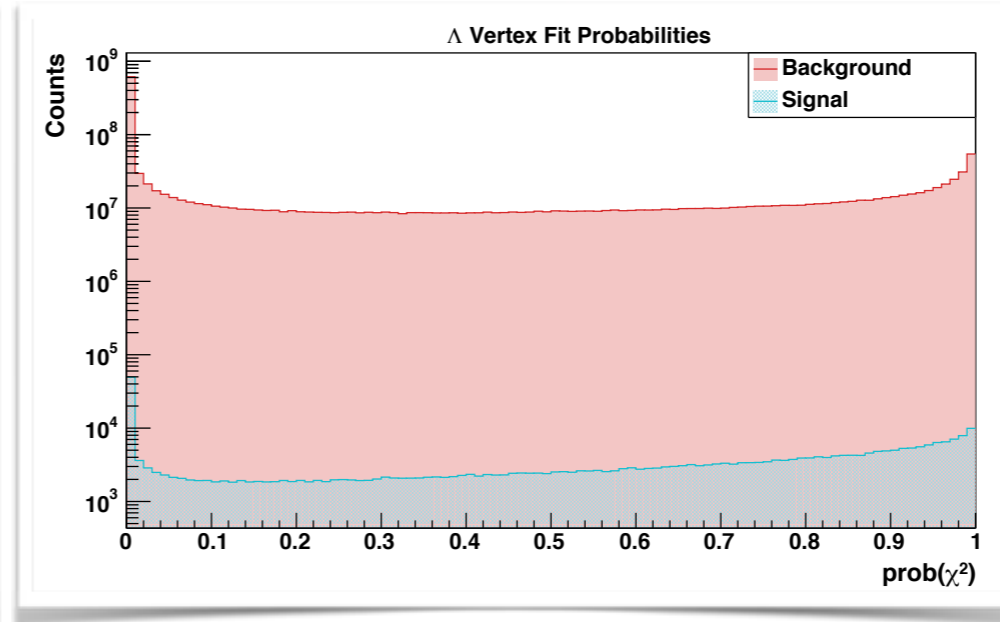
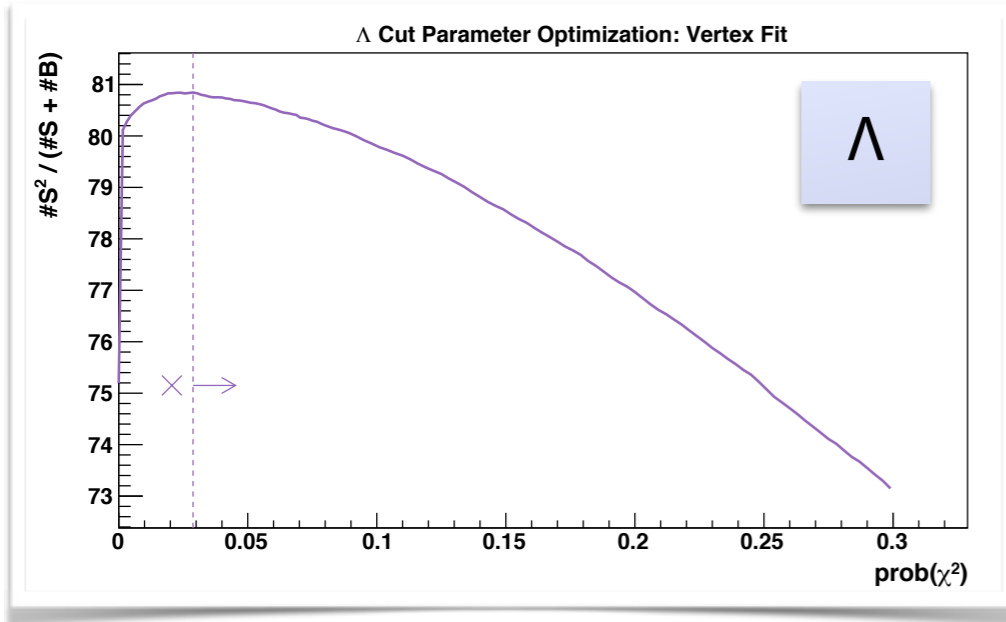
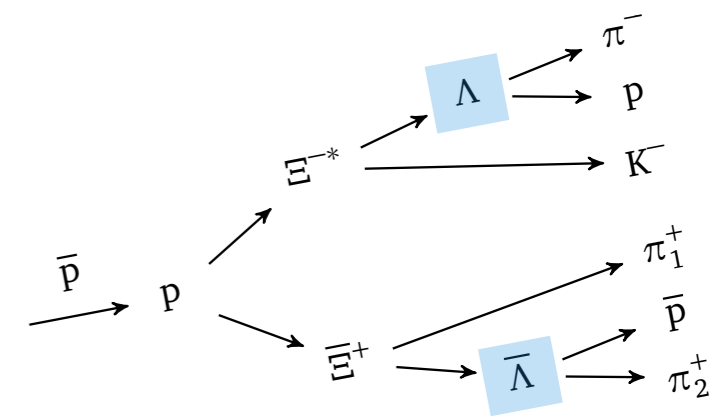
$$S = \frac{N_{\text{sig}}^2}{N_{\text{sig}} + N_{\text{bkg}}}$$

- Maximum of S determines optimal cut parameter

Background scaling:

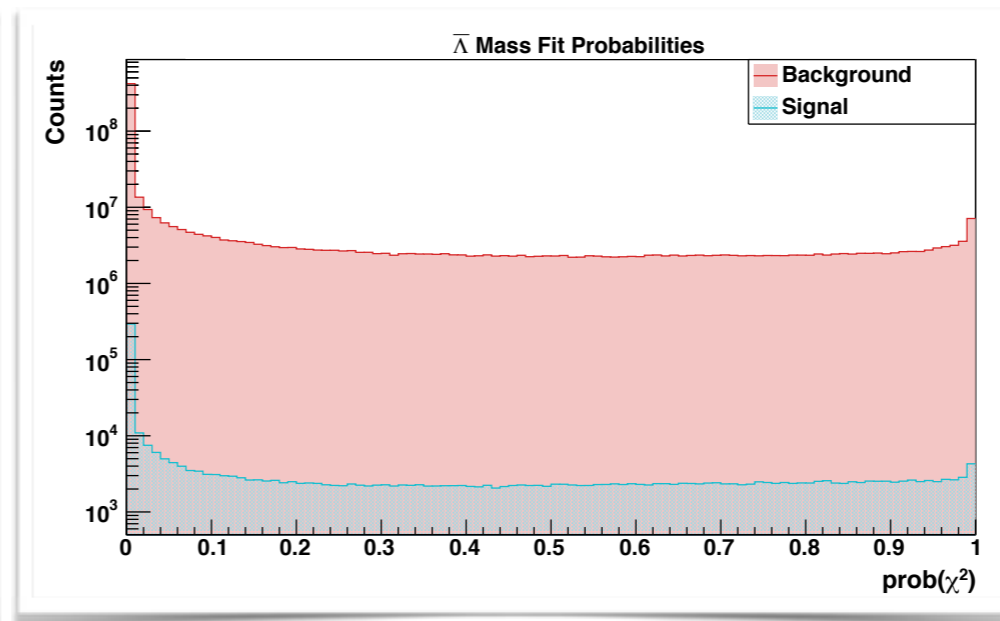
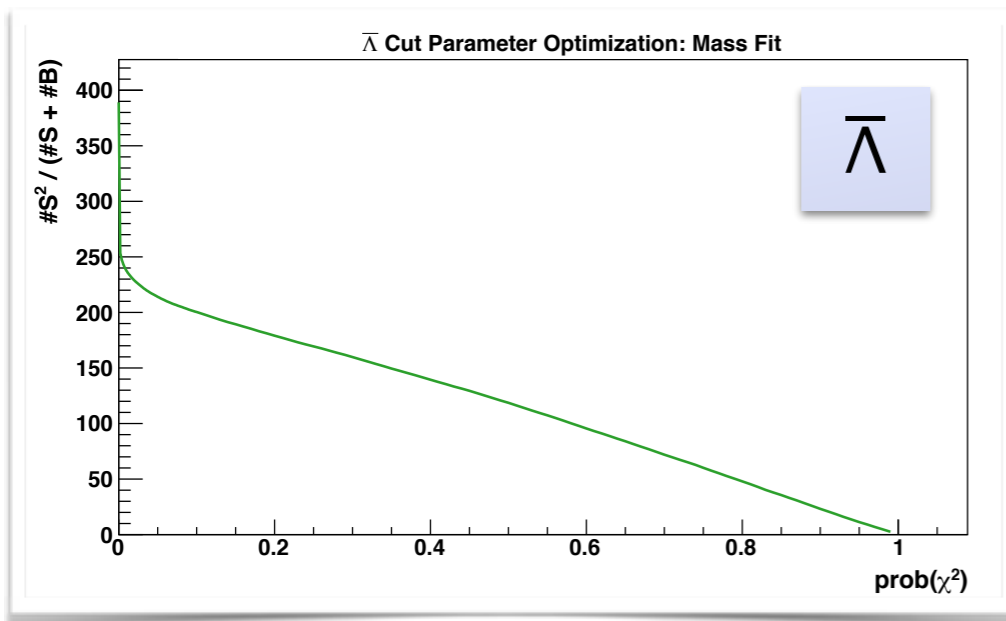
$$B = \frac{N_{\text{sig,gen}} / (\sigma_{\text{sig}} \times \text{BR})}{N_{\text{bkg}} / \sigma_{\text{bkg}}}$$

Λ Reconstruction — Vertex & Mass Fit



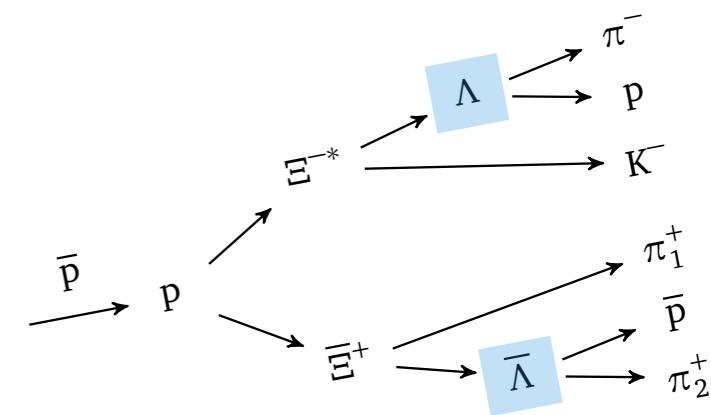
Λ vertex fit:
 $\text{prob}(\chi^2) > 0.029$

Λ mass c. fit:
 $\text{prob}(\chi^2) > 0.037$



$\bar{\Lambda}$ vtx. & mass c. fit:
 optimization fails
 $\Rightarrow \text{prob}(\chi^2) > 0.01$
 (old value)

Λ Reconstruction — Cut Optimization



Cut Parameter	Signal $\Lambda/\bar{\Lambda}$	Background $\Lambda/\bar{\Lambda}$	\mathcal{S}
<i>No cut</i>	353,585 (100%)	2,132,407 (100%)	71
Λ Vertex fit: $\text{prob}(\chi^2) > 0.029$	297,962 (84.3%)	1,329,868 (62.4%)	81
Mass fit: $\text{prob}(\chi^2) > 0.037$	236,003 (66.7%)	504,802 (23.7%)	134
Best after both fits	210,761 (59.6%)	270,433 (12.7%)	199
<i>No cut</i>	558,879 (100%)	868,695 (100%)	435
$\bar{\Lambda}$ Vertex fit: $\text{prob}(\chi^2) > 0.01$	431,575 (77.2%)	758,350 (87.3%)	297
Mass fit: $\text{prob}(\chi^2) > 0.01$	264,658 (47.4%)	356,967 (41.1%)	237
Best after both fits	194,907 (34.9%)	317,156 (36.5%)	145

shown

combined

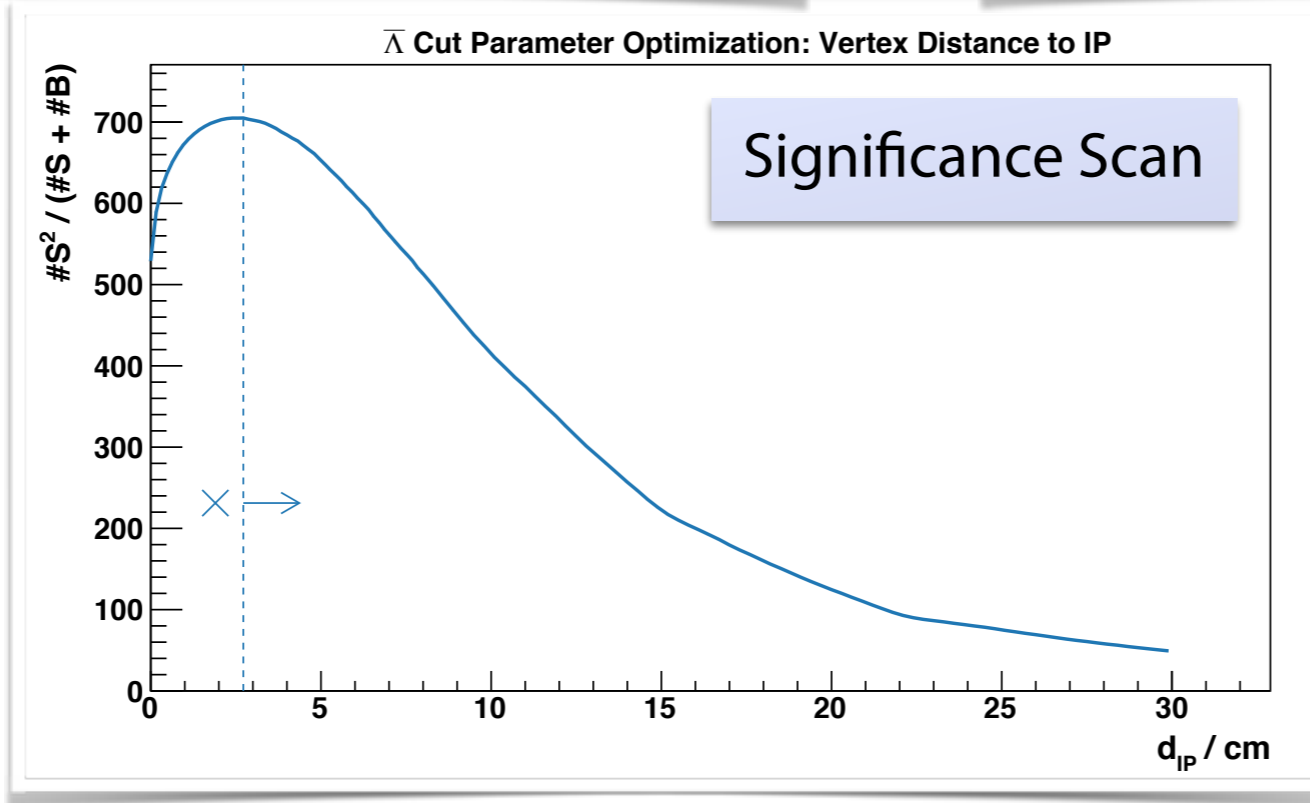
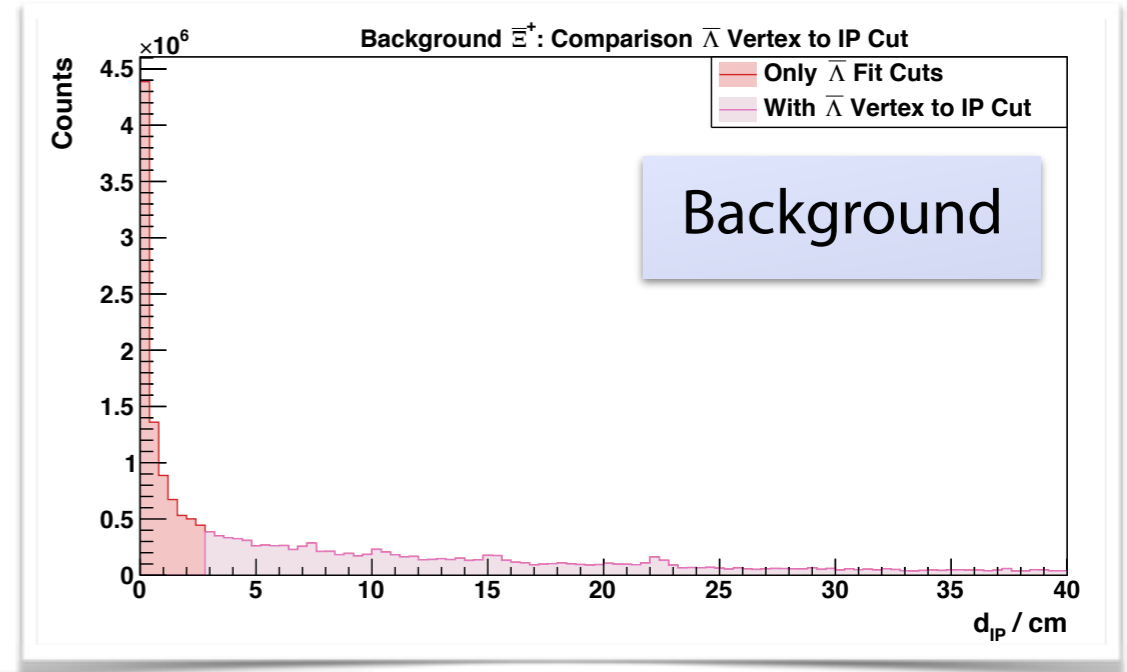
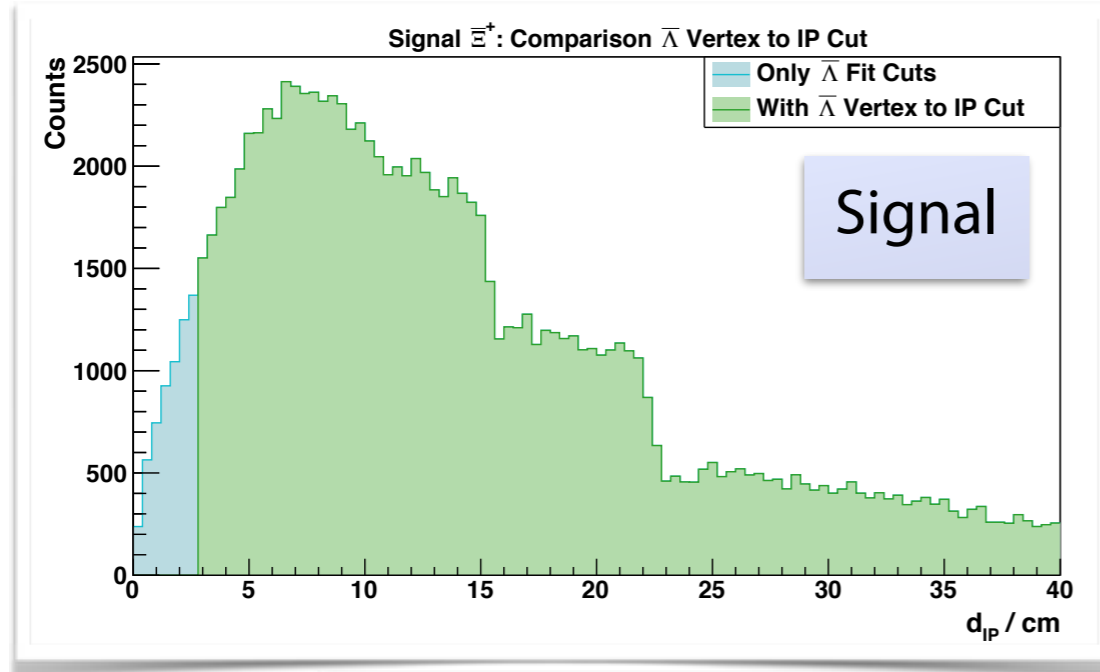
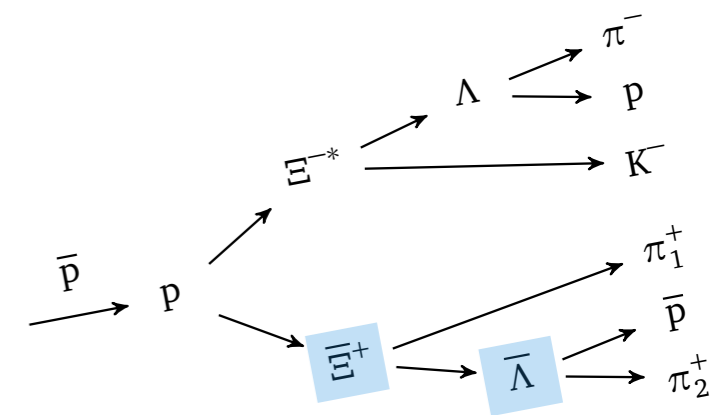
shown

combined

Background needs to be multiplied with factor **825.6** to be comparable.

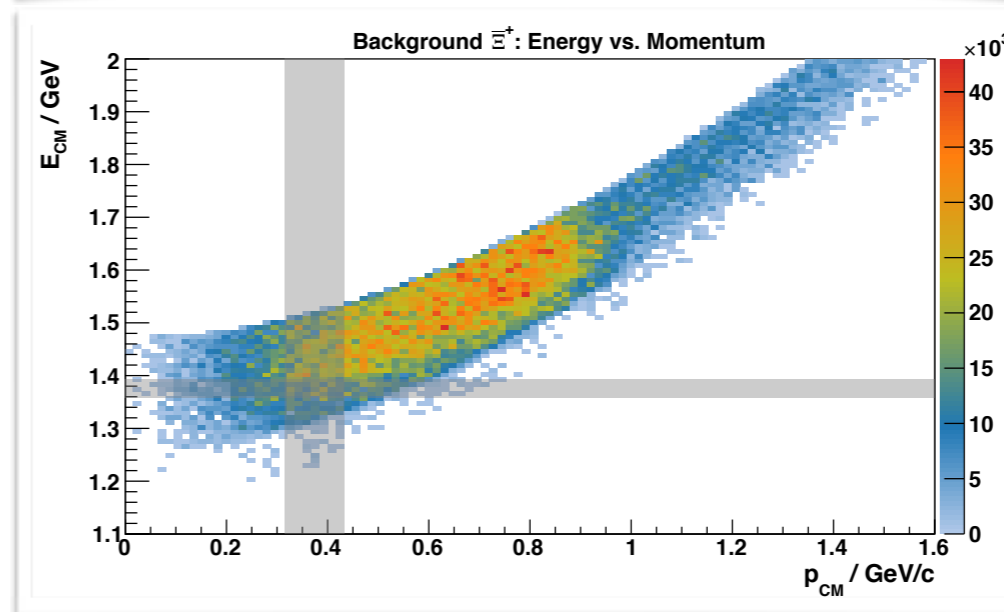
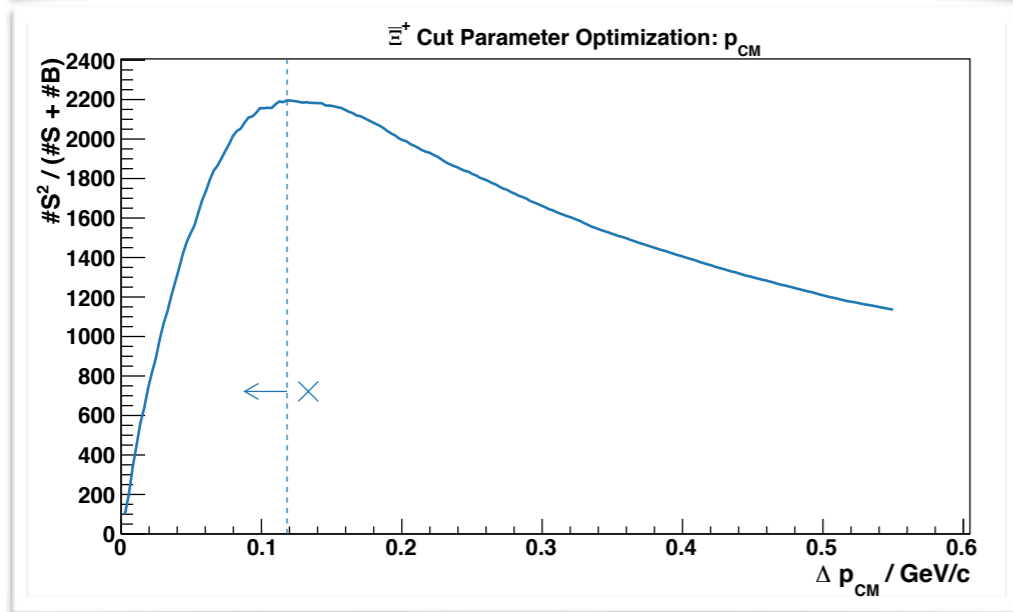
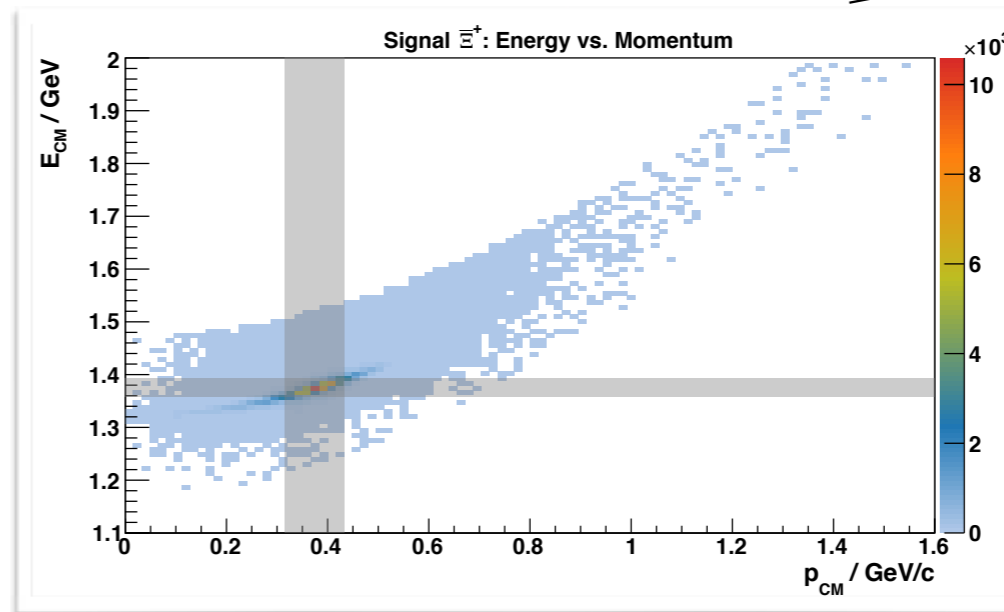
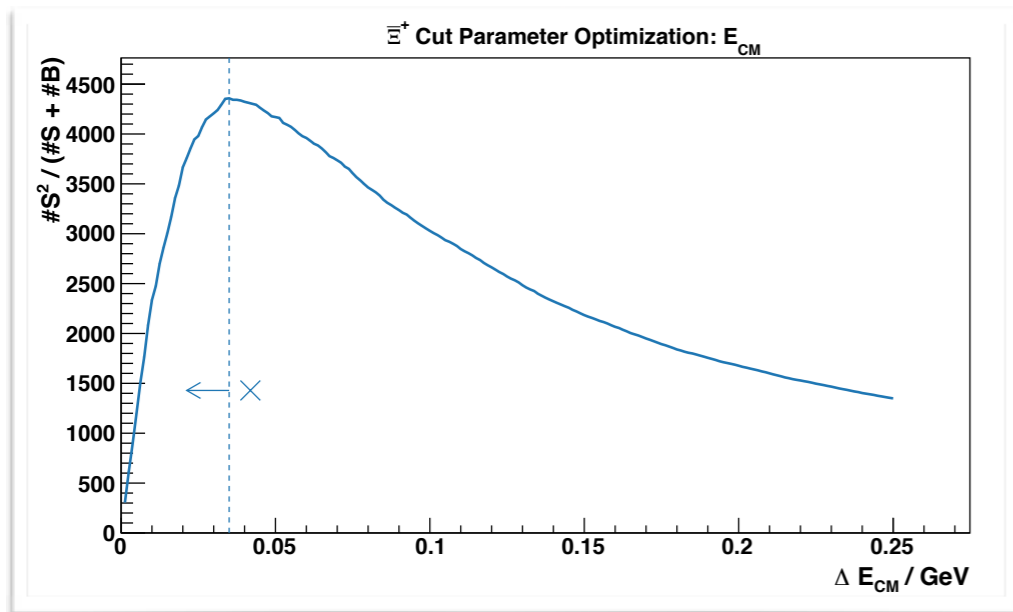
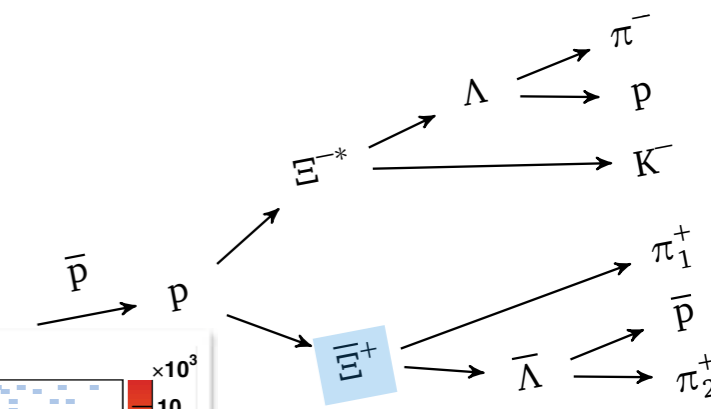
Ξ^+ Reconstruction — $\bar{\Lambda}$ Vertex Position

- $\bar{\Lambda}$ is produced by Ξ^+
 \Rightarrow decay vertex after $2 \times c\tau \approx 8$ cm



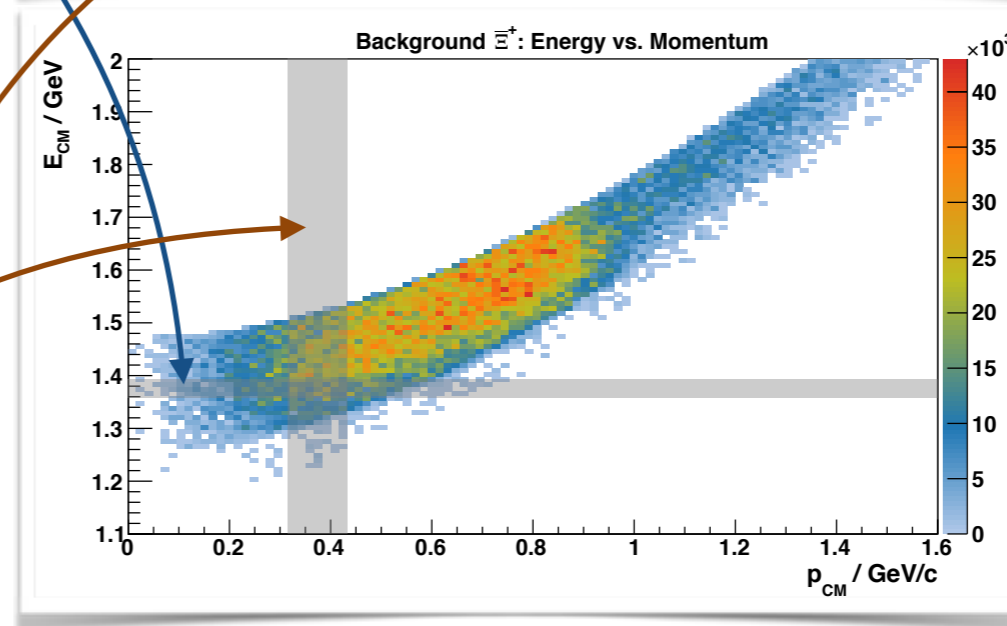
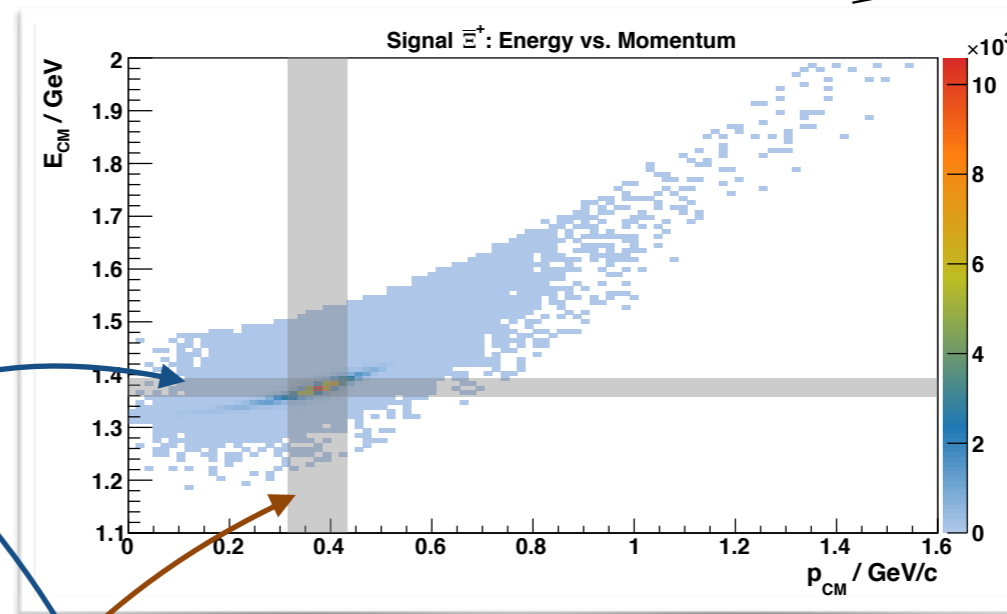
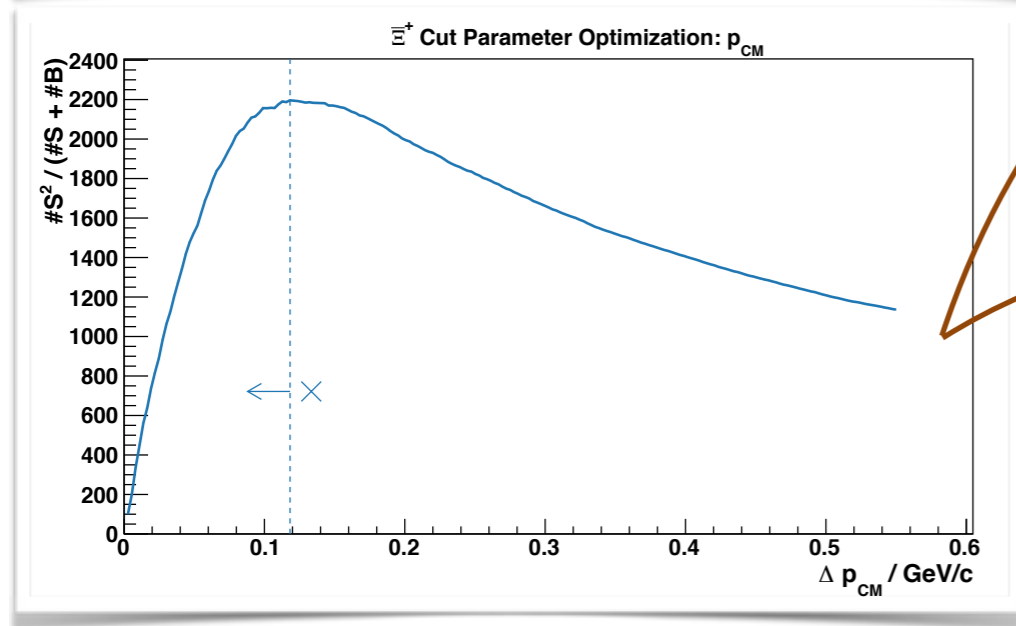
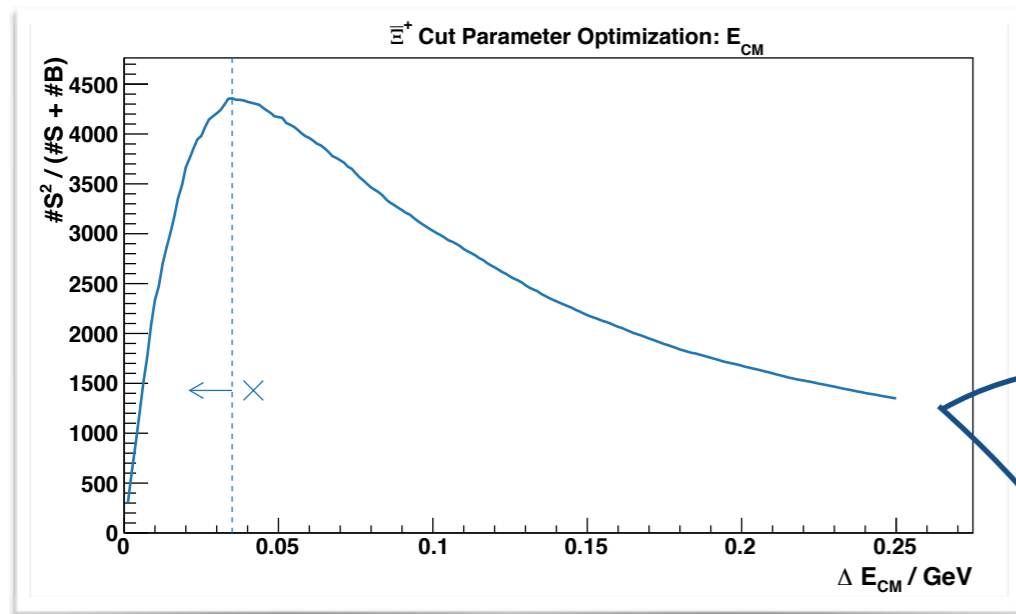
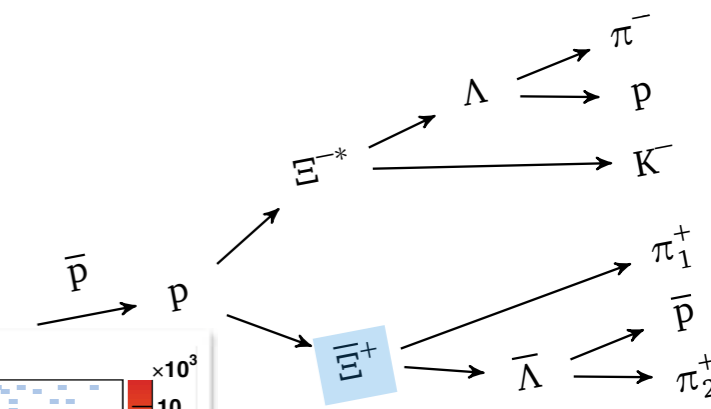
$\Rightarrow d_{IP} > 2.8$ cm

Ξ^+ Reconstruction — E vs. p



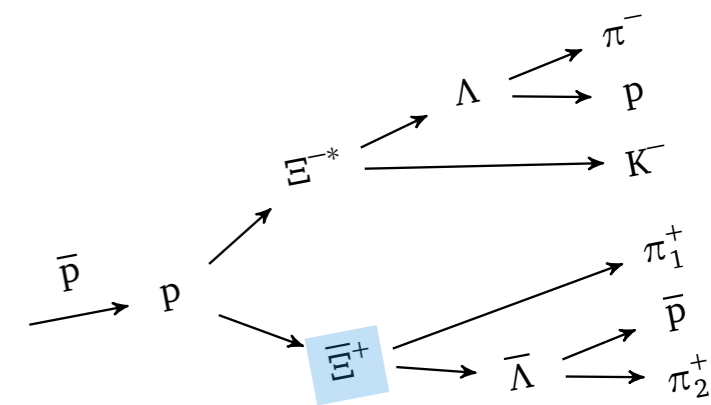
- Symmetric increase of window around expected value
- ⇒ Results: $1.357 \text{ GeV} < E_{\text{CM}} < 1.393 \text{ GeV}$;
 $0.316 \text{ GeV}/c < p_{\text{CM}} < 0.434 \text{ GeV}/c$

Ξ^+ Reconstruction — E vs. p



- Symmetric increase of window around expected value
 \Rightarrow Results: $1.357 \text{ GeV} < E_{\text{CM}} < 1.393 \text{ GeV}$;
 $0.316 \text{ GeV/c} < p_{\text{CM}} < 0.434 \text{ GeV/c}$

Ξ^+ Reconstruction — Cut Optimization



Cut Parameter	Unit	Condition	$N_{\Xi^+, \text{sig}} / \%$ (119,827)	$N_{\Xi^+, \text{bkg}} / \%$ (32,674 \times \mathcal{B})	\mathcal{S}
$\bar{\Lambda}$ kinematic cuts			100.0	100.0	529
$\bar{\Lambda}$ Decay Vertex: d_{IP}	cm	$x > 2.80$	94.9	67.5	705
POCA($\bar{\Lambda} \pi_1^+$): pocaQA	cm	$7.70 < x$	80.3	50.0	680
POCA($\Xi^+ K^-$): pocaQA	cm	$26.0 < x$	82.1	4.6	7222
Prop. to IP: d_{IP}	cm	$0.92 < x$	73.0	21.3	1314
ΔE_{CM}	GeV	$1.357 < x < 1.393$	65.0	4.9	4357
ΔP_{CM}	GeV/c	$0.316 < x < 0.434$	68.3	11.0	2196
Inclusive (no K^- , no back-propagation)			49.9	0.58	16,497
Inclusive (no K^-)			45.5	0.22	26,250
Semi-inclusive (no back-propagation)			41.2	0.10	31,831
Semi-inclusive (all)			37.6	0.05	34,790

shown

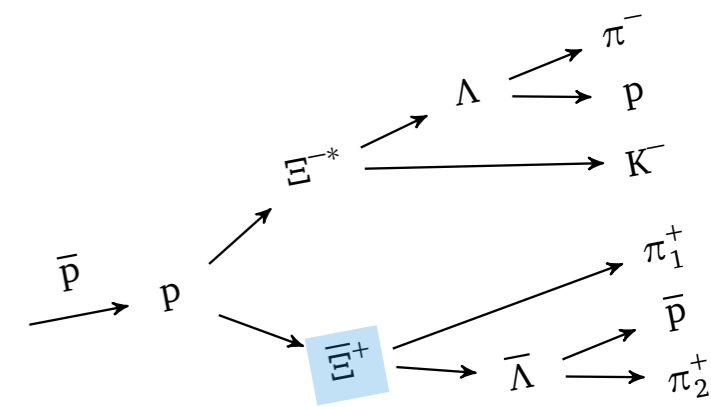
shown

combined

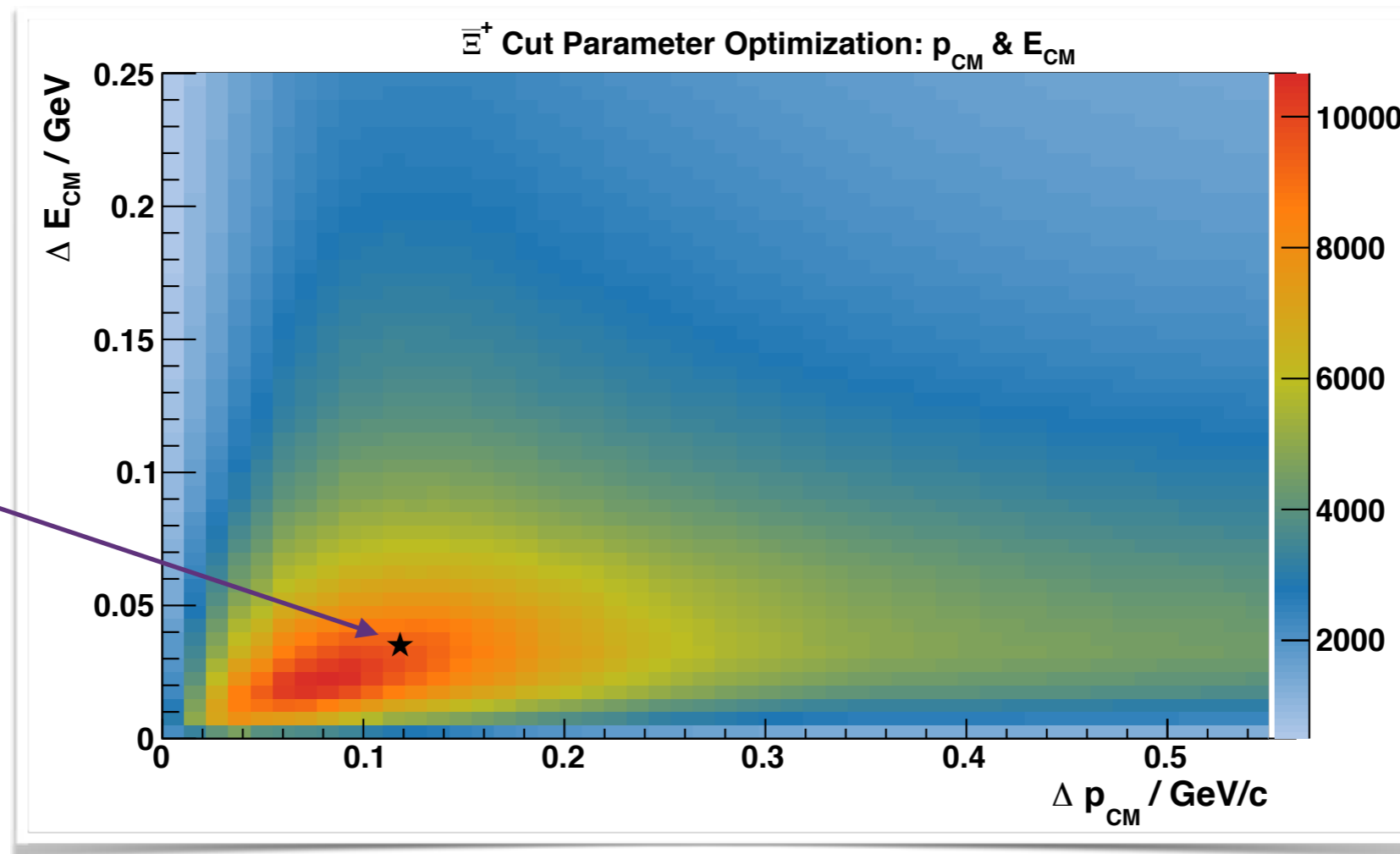
Background needs to be multiplied with factor **826.5** to be comparable.

Two-Dimensional Significance Scan

- Vary two parameters simultaneously



Individually
found
optimum



- Individually

$$\Rightarrow 1.357 \text{ GeV} < E_{\text{CM}} < 1.393 \text{ GeV};$$

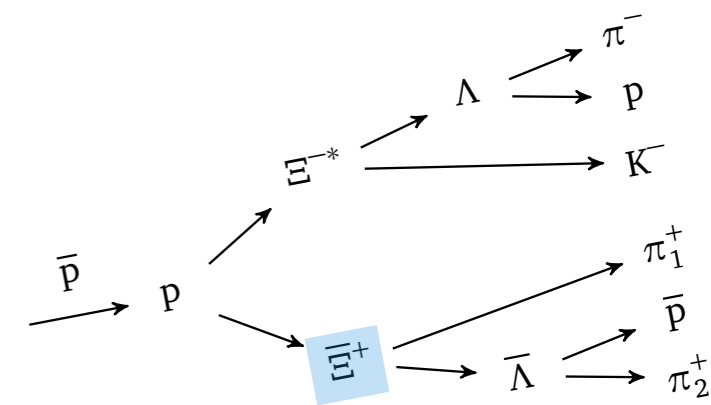
$$0.316 \text{ GeV}/c < p_{\text{CM}} < 0.434 \text{ GeV}/c$$

- Simultaneously

$$\Rightarrow 1.363 \text{ GeV} < E_{\text{CM}} < 1.387 \text{ GeV};$$

$$0.331 \text{ GeV}/c < p_{\text{CM}} < 0.419 \text{ GeV}/c$$

Ξ^+ Reconstruction — Cut Optimization



Cut Parameter	Unit	Condition	$N_{\Xi^+, \text{sig}} / \%$ (119,827)	$N_{\Xi^+, \text{bkg}} / \%$ (32,674 \times \mathcal{B})	\mathcal{S}
$\bar{\Lambda}$ kinematic cuts			100.0	100.0	529
$\bar{\Lambda}$ Decay Vertex: d_{IP}	cm	$x > 4.40$	89.2	62.3	674
POCA($\bar{\Lambda} \pi_1^+$): pocaQA	cm	$7.70 < x$	80.3	50.0	680
POCA($\Xi^+ K^-$): pocaQA	cm	$26.0 < x$	82.1	4.6	7222
Prop. to IP: d_{IP}	cm	$0.60 < x$	67.6	18.4	1301
ΔE_{CM}	GeV	$1.363 < x < 1.387$	53.1	3.5	3980
ΔP_{CM}	GeV/c	$0.331 < x < 0.419$	57.7	8.2	2084
Semi-inclusive (no back-propagation)			34.9	0.06	30,023
Semi-inclusive (all)			27.7	0.02	29,494

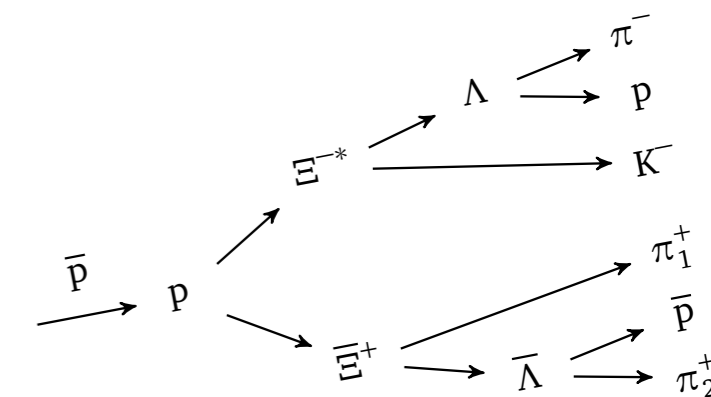
shown

combined

Background needs to be multiplied with factor 826.5 to be comparable.

15 % less signal, 40 % less background than individual optimization

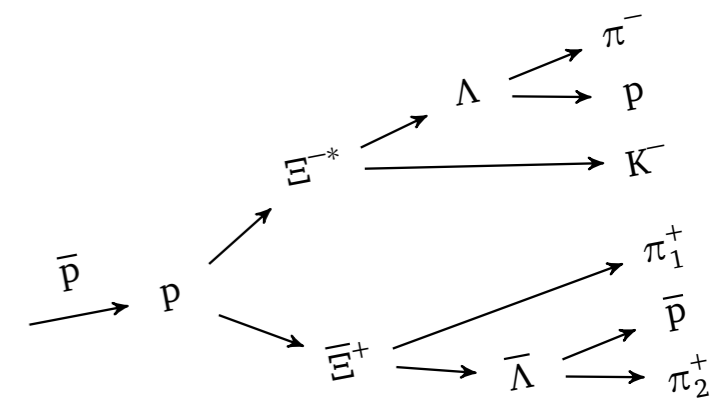
Reconstruction Summary



Particle	$N_{\text{sig}} (\epsilon_{\text{sig}})$	$N_{\text{bkg}} (\epsilon_{\text{bkg}})$	S
<i>Generated</i>	499,750 (100 %)	47,367,000 (100 %)	
Λ	210,761 (42.2 %)	270,433 (0.6 %)	199
$\bar{\Lambda}$	194,907 (39.0 %)	317,156 (0.7 %)	145
Ξ^{-*}	107,893 (21.6 %)	26 (5.5×10^{-7})	89,990
Ξ^{+}	41,875 (8.4 %)	20 (4.2×10^{-7})	30,023
$\Xi^{+}\Xi^{-*}$, only 4C cut	11,011 (2.2 %)	3 (0.6×10^{-7})	8142
$\Xi^{+}\Xi^{-*}$, + Ξ^{+} cuts	4012 (0.8 %)	1 (0.2×10^{-7})	3034

- **Reconstruction efficiency: 2.2 %**
 - 6756 h⁻¹ fully reconstructed signals at $L = 2 \times 10^{32} /(\text{cm}^2 \text{ s})$
 - 338 h⁻¹ fully reconstructed signals at $L = 1 \times 10^{31} /(\text{cm}^2 \text{ s})$
- Very good **background suppression** possibilities
 - Conservative cuts: **3879** background events after scaling
 - Same time frame: **11,011** exclusive signal events
 - More optimizations possible (with final detector implementation?)

Reconstruction Summary



Thank you!

a.zambanini@fz-juelich.de

Particle	$N_{\text{sig}} (\epsilon_{\text{sig}})$	$N_{\text{bkg}} (\epsilon_{\text{bkg}})$	S
<i>Generated</i>	499,750 (100 %)	47,367,000 (100 %)	
Λ	210,761 (42.2 %)	270,433 (0.6 %)	199
$\bar{\Lambda}$	194,907 (39.0 %)	317,156 (0.7 %)	145
Ξ^{-*}	107,893 (21.6 %)	26 (5.5×10^{-7})	89,990
Ξ^{+}	41,875 (8.4 %)	20 (4.2×10^{-7})	30,023
$\Xi^{+}\Xi^{-*}$, only 4C cut	11,011 (2.2 %)	3 (0.6×10^{-7})	8142
$\Xi^{+}\Xi^{-*}$, + Ξ^{+} cuts	4012 (0.8 %)	1 (0.2×10^{-7})	3034

- **Reconstruction efficiency: 2.2 %**
 - 6756 h⁻¹ fully reconstructed signals at $L = 2 \times 10^{32} /(\text{cm}^2 \text{ s})$
 - 338 h⁻¹ fully reconstructed signals at $L = 1 \times 10^{31} /(\text{cm}^2 \text{ s})$
- Very good **background suppression** possibilities
 - Conservative cuts: **3879** background events after scaling
 - Same time frame: **11,011** exclusive signal events
 - More optimizations possible (with final detector implementation?)

BACKUP

Selected Decay Modes

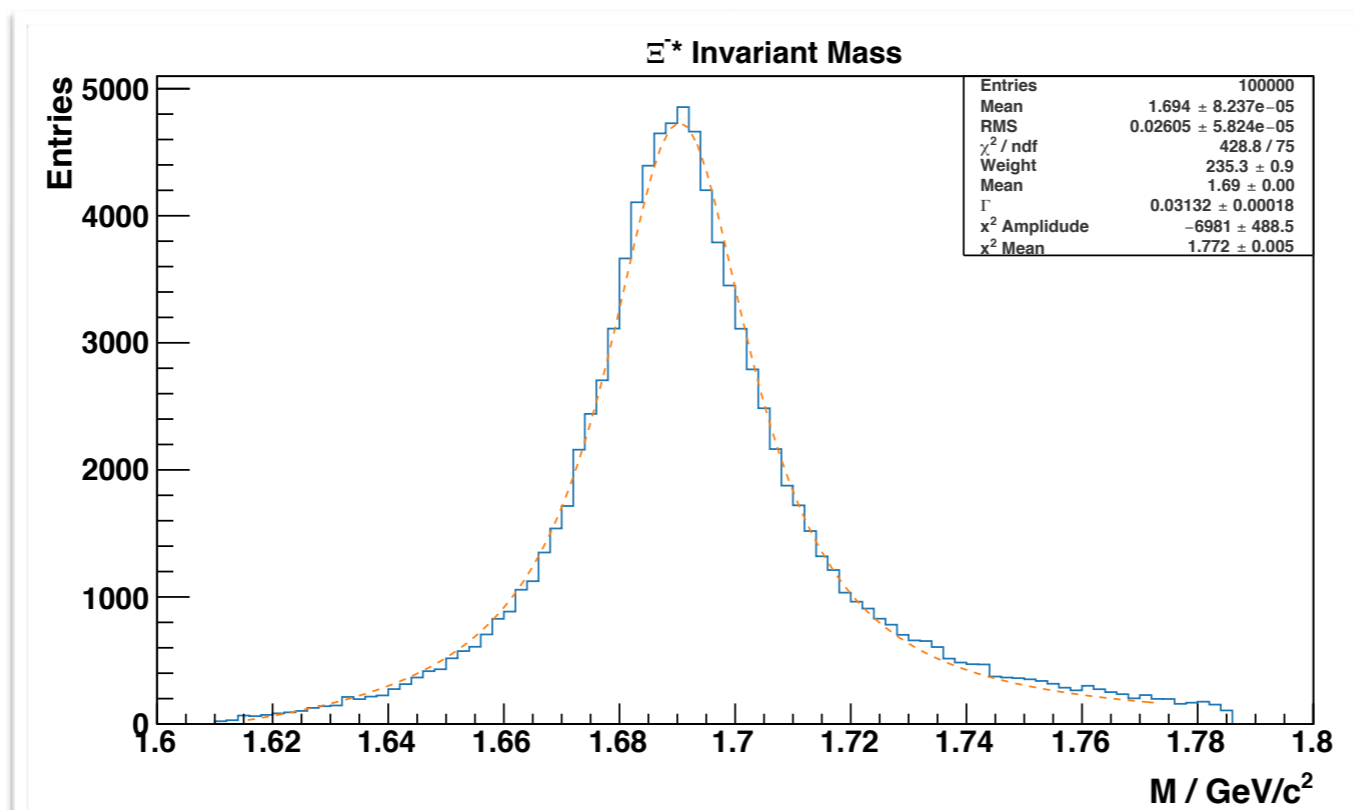
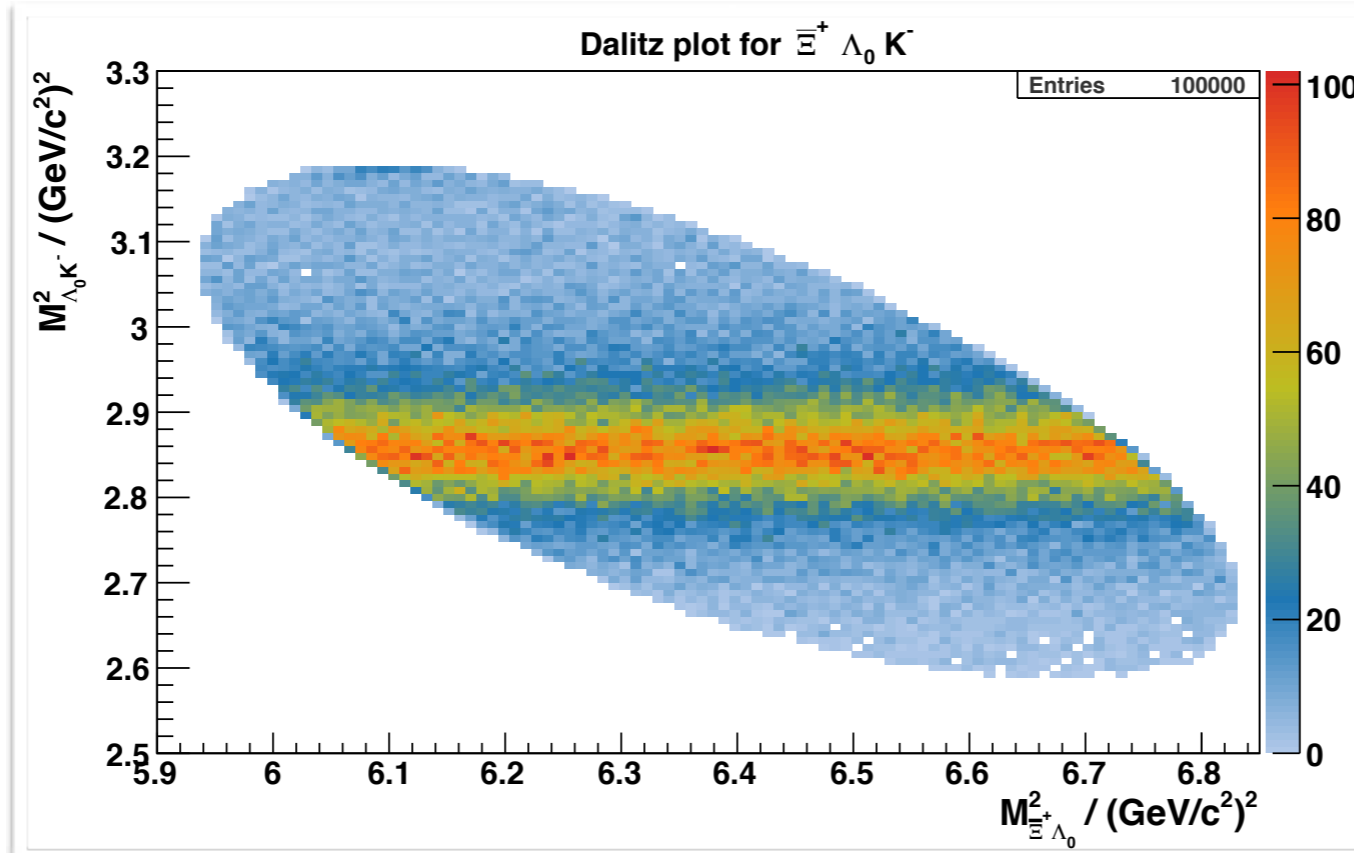
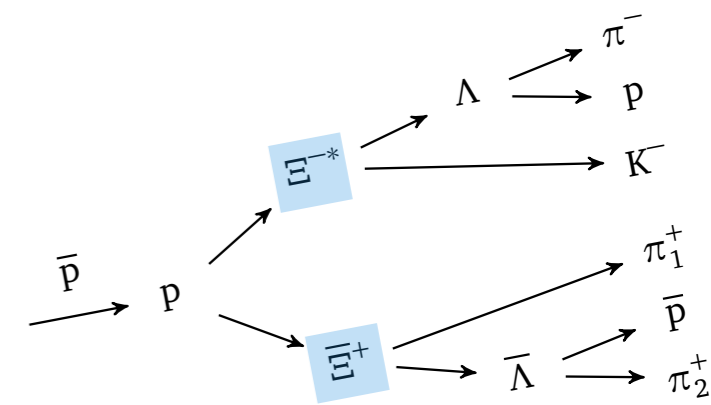
- Reduction from selected decay modes:

- $2 \times \Lambda \rightarrow p\pi^-$: 40 %
- $\Xi \rightarrow \Lambda\pi^-$: 99.9 %
- $\Xi(1690) \rightarrow \Lambda K^-$: ?

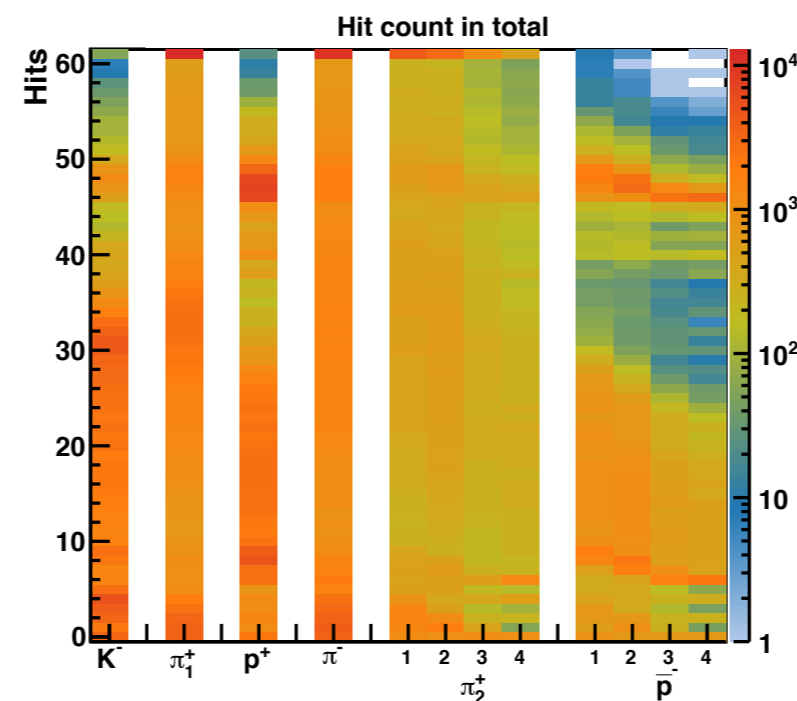
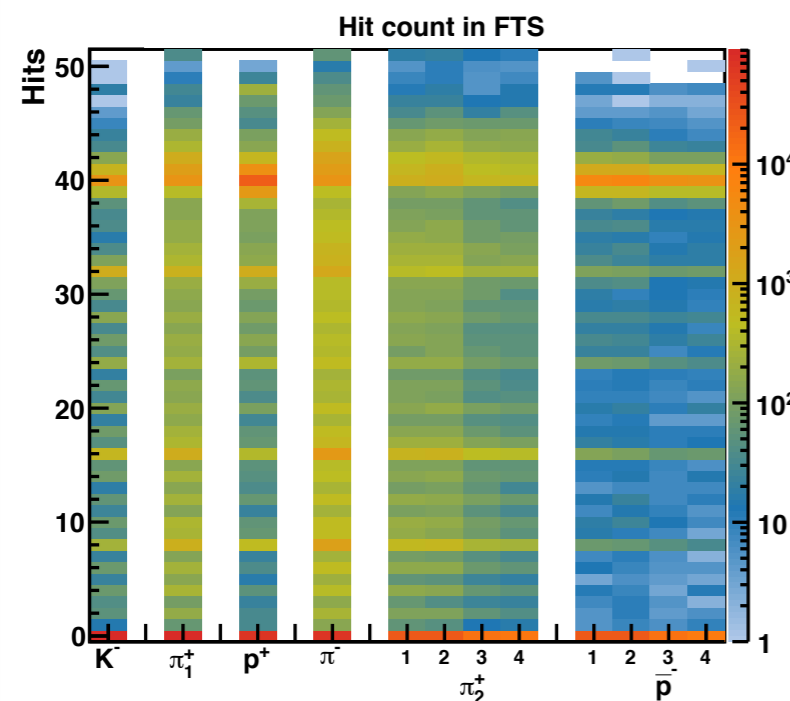
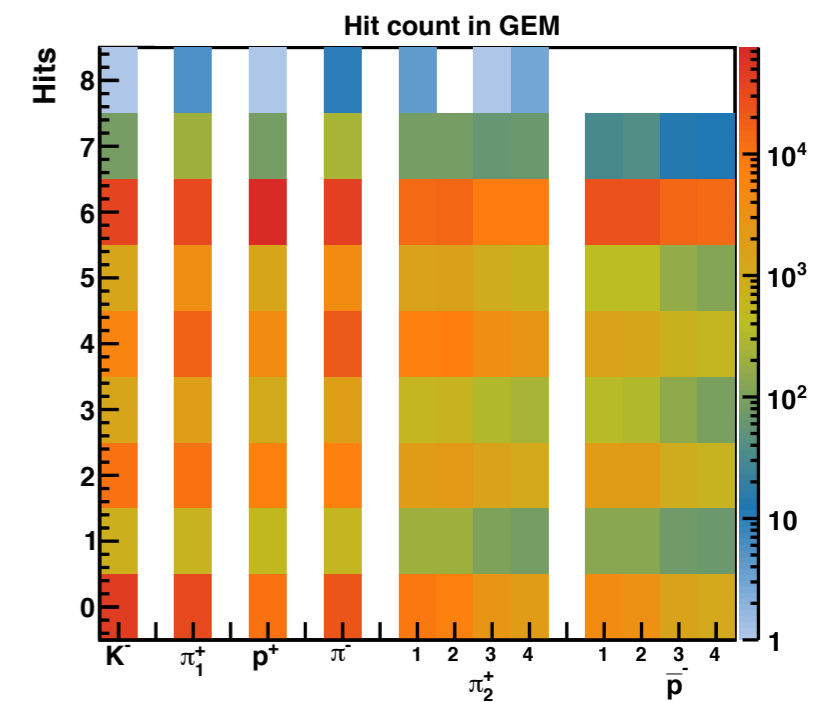
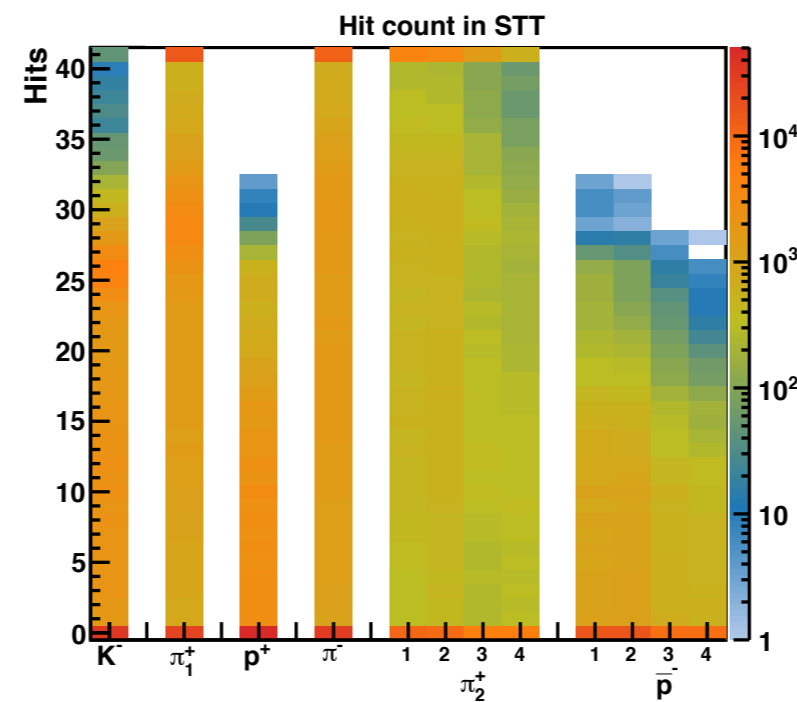
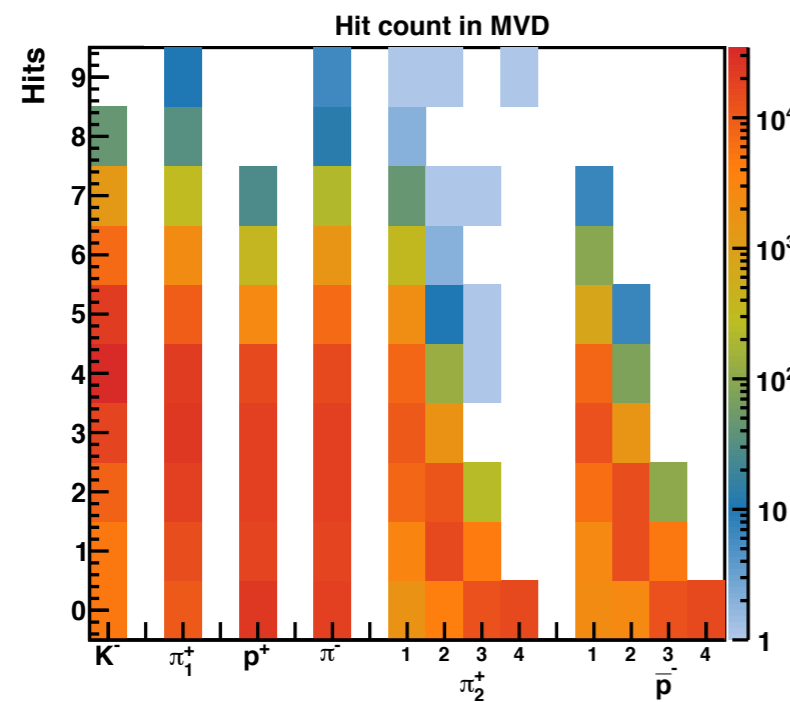
Λ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$p\pi^-$	$(63.9 \pm 0.5) \%$	101
$n\pi^0$	$(35.8 \pm 0.5) \%$	104
$n\gamma$	$(1.75 \pm 0.15) \times 10^{-3}$	162
$p\pi^- \gamma$	[c] $(8.4 \pm 1.4) \times 10^{-4}$	101
$pe^- \bar{\nu}_e$	$(8.32 \pm 0.14) \times 10^{-4}$	163
$p\mu^- \bar{\nu}_\mu$	$(1.57 \pm 0.35) \times 10^{-4}$	131

Ξ^- DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$\Lambda\pi^-$	$(99.887 \pm 0.035) \%$		140
$\Sigma^- \gamma$	$(1.27 \pm 0.23) \times 10^{-4}$		118
$\Lambda e^- \bar{\nu}_e$	$(5.63 \pm 0.31) \times 10^{-4}$		190
$\Lambda \mu^- \bar{\nu}_\mu$	$(3.5^{+3.5}_{-2.2}) \times 10^{-4}$		163
$\Sigma^0 e^- \bar{\nu}_e$	$(8.7 \pm 1.7) \times 10^{-5}$		123
$\Sigma^0 \mu^- \bar{\nu}_\mu$	$< 8 \times 10^{-4}$	90%	70
$\Xi^0 e^- \bar{\nu}_e$	$< 2.3 \times 10^{-3}$	90%	7

EvtGen — $\Xi^- (1690)$



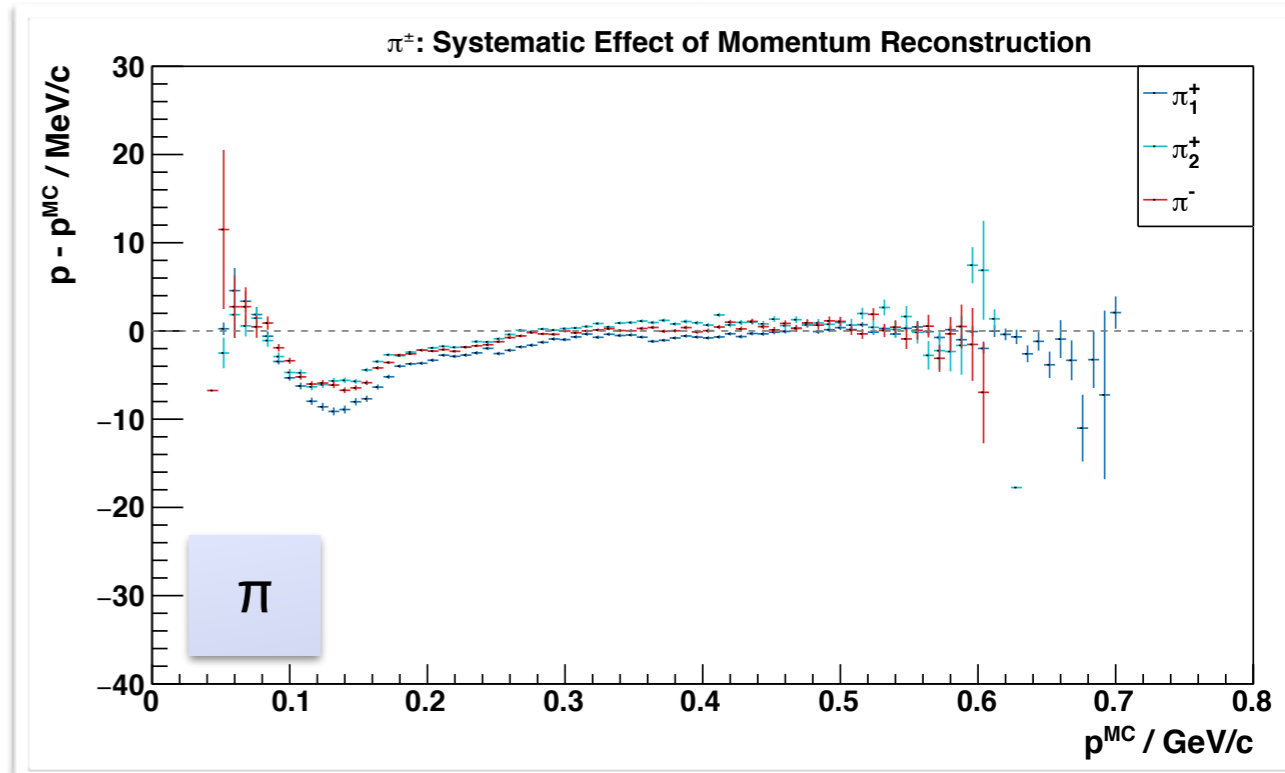
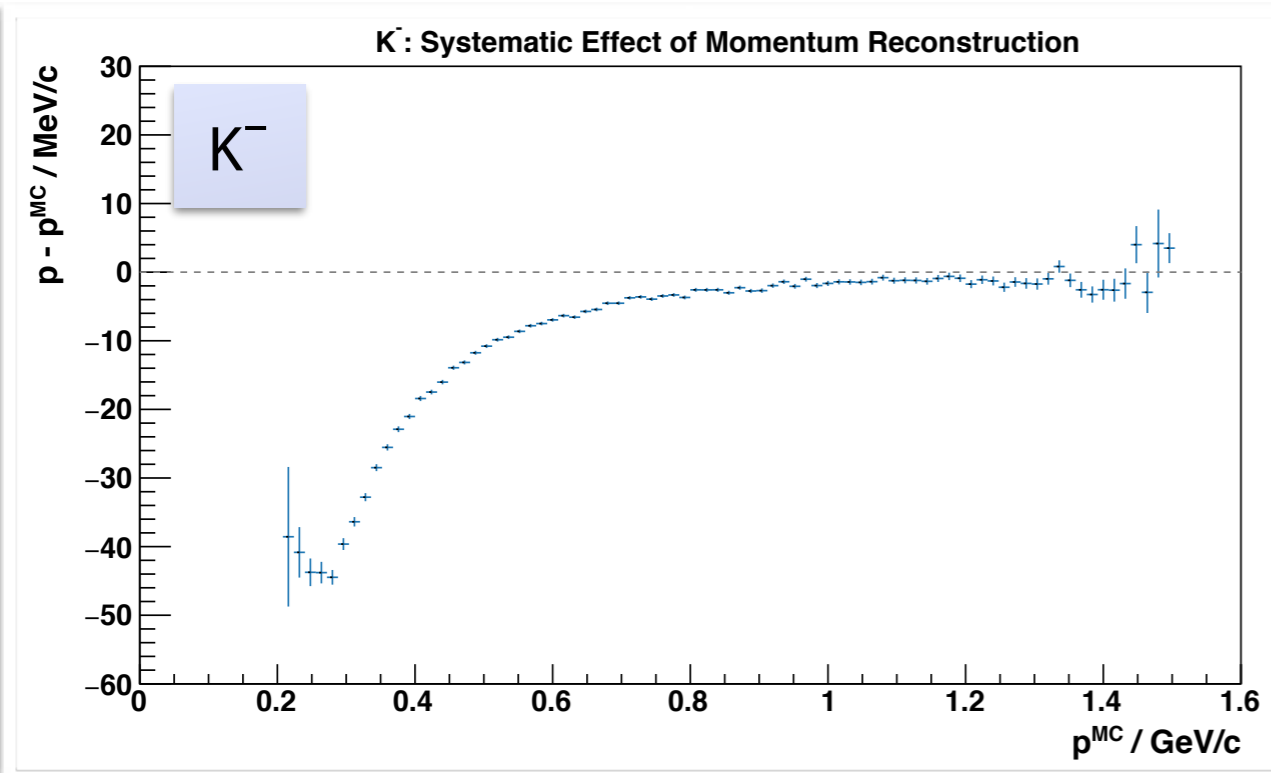
Detector Response — Hit Counts



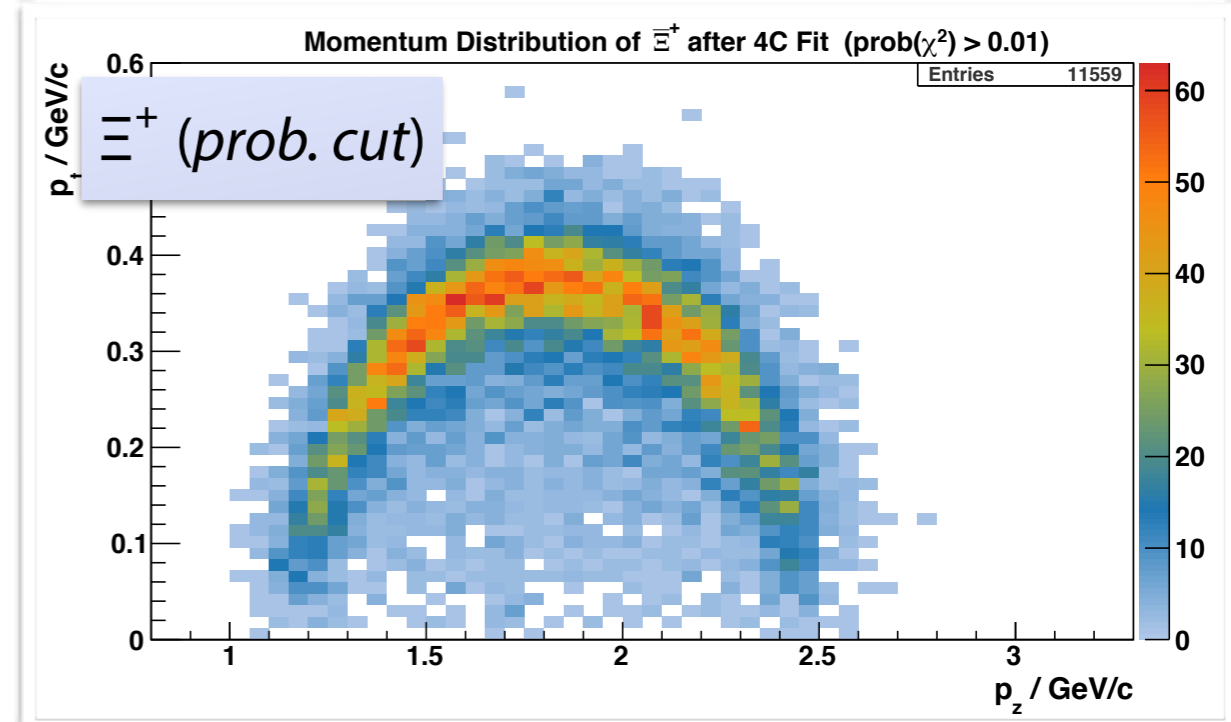
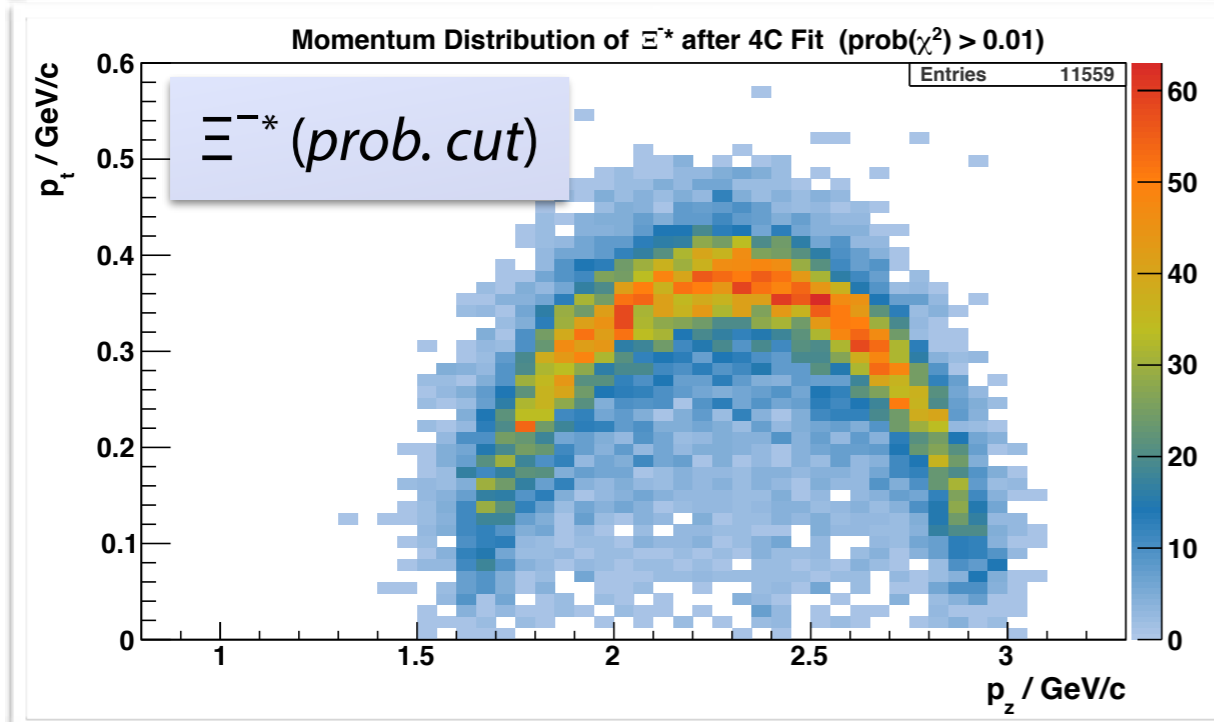
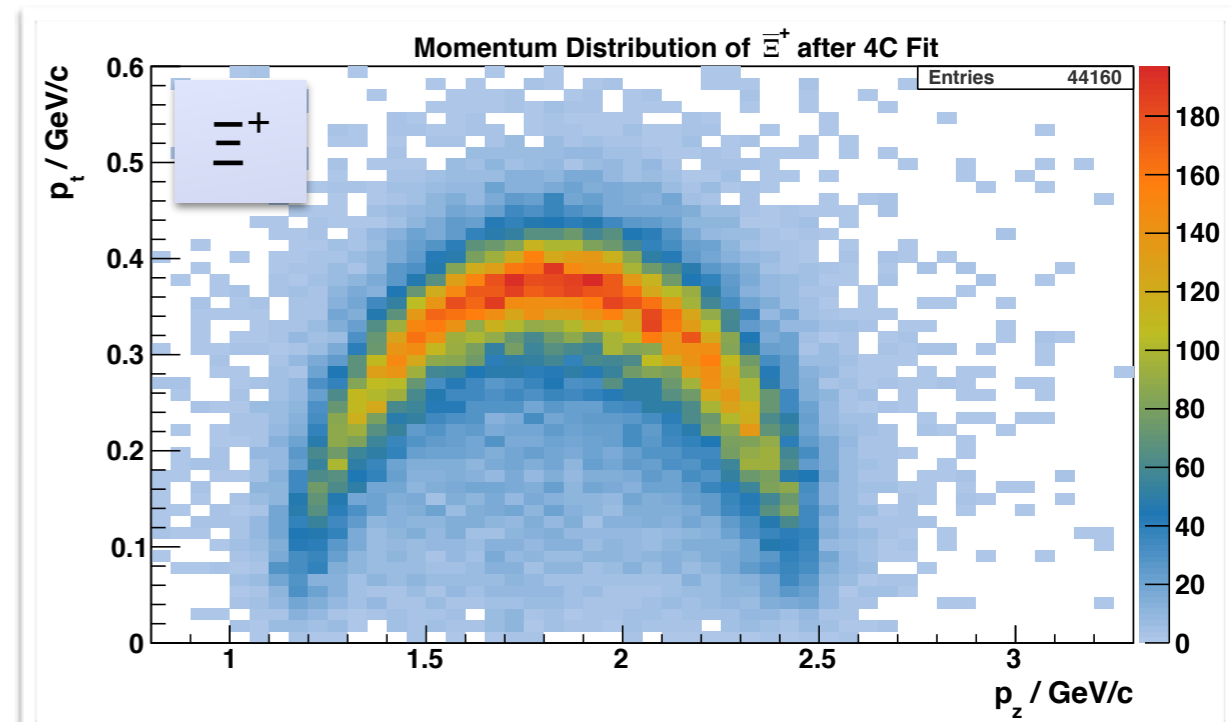
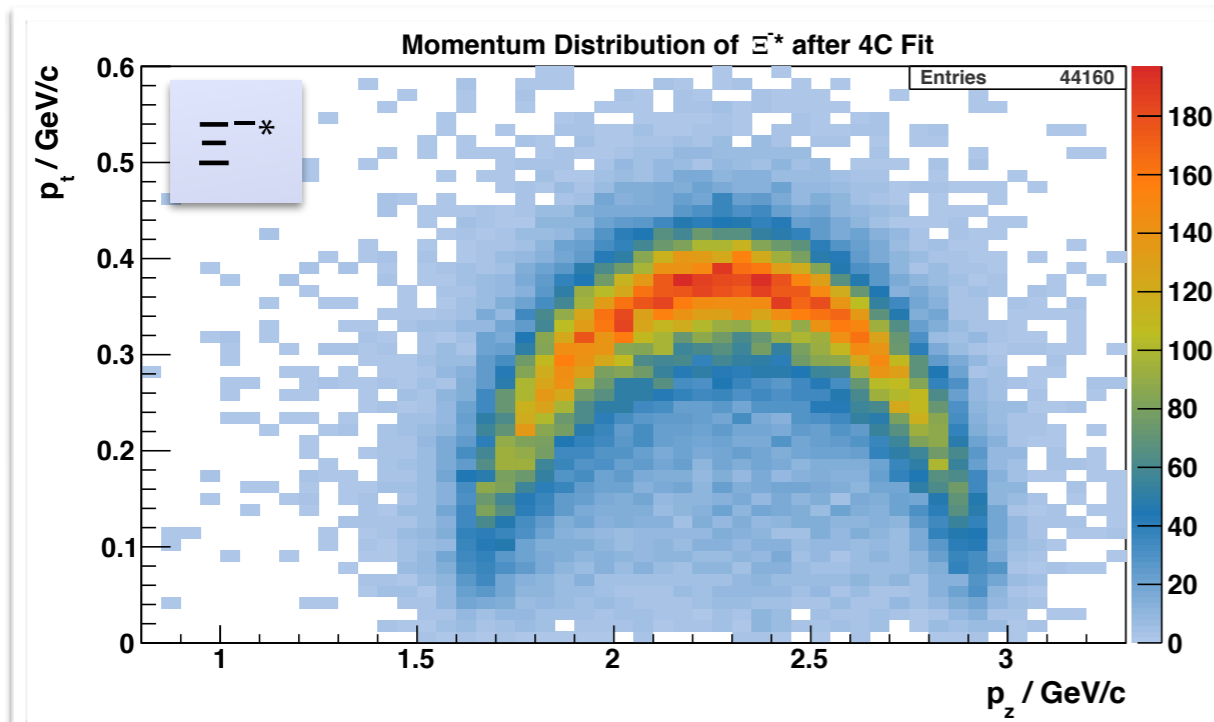
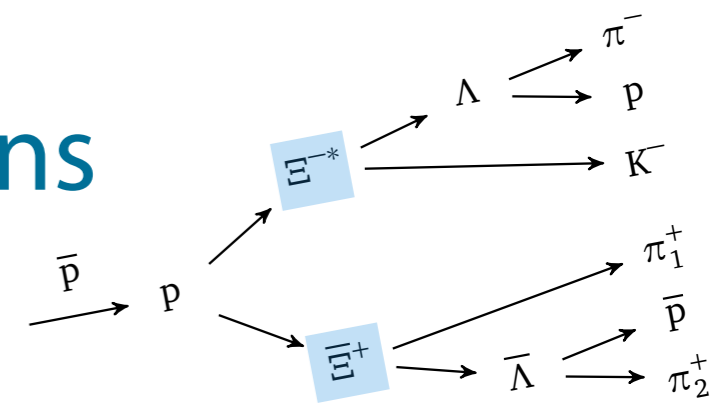
- Range 1: $|\vec{ld}_{\text{vertex}}| < 10 \text{ cm}$
- Range 2: $10 \text{ cm} \leq |\vec{ld}_{\text{vertex}}| < 20 \text{ cm}$
- Range 3: $20 \text{ cm} \leq |\vec{ld}_{\text{vertex}}| < 30 \text{ cm}$
- Range 4: $30 \text{ cm} \leq |\vec{ld}_{\text{vertex}}|$

Note: Bins for maximum hit count contain overflow.

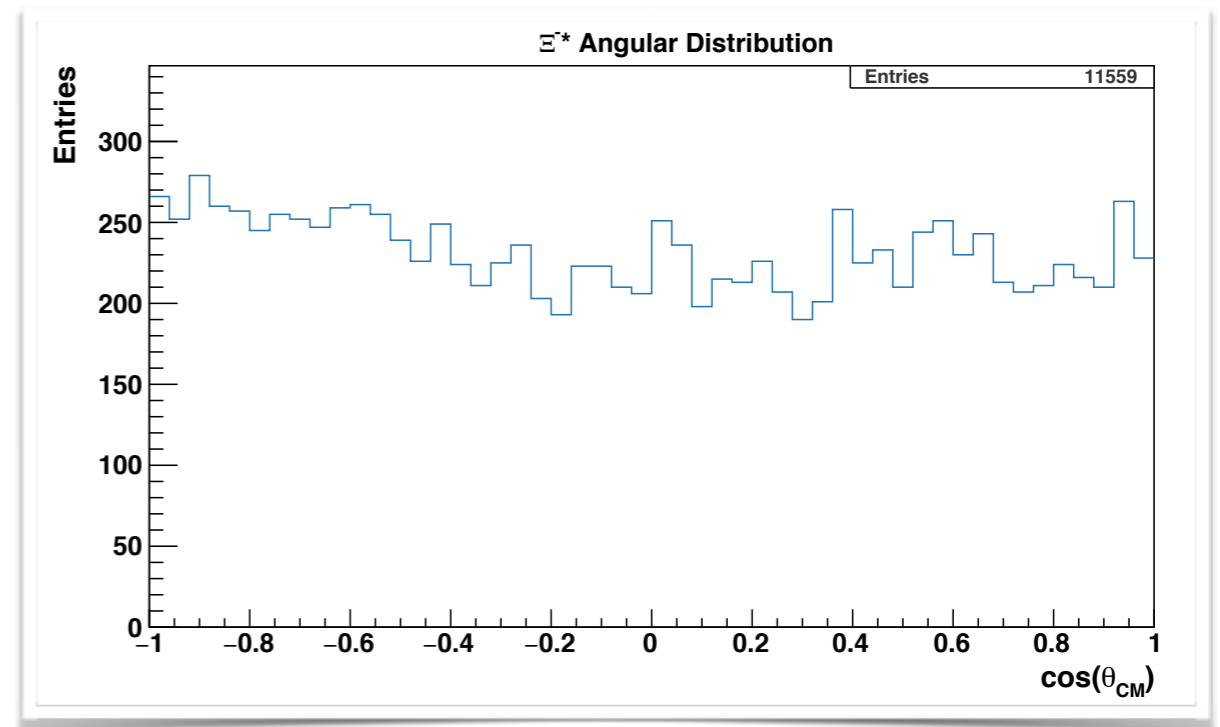
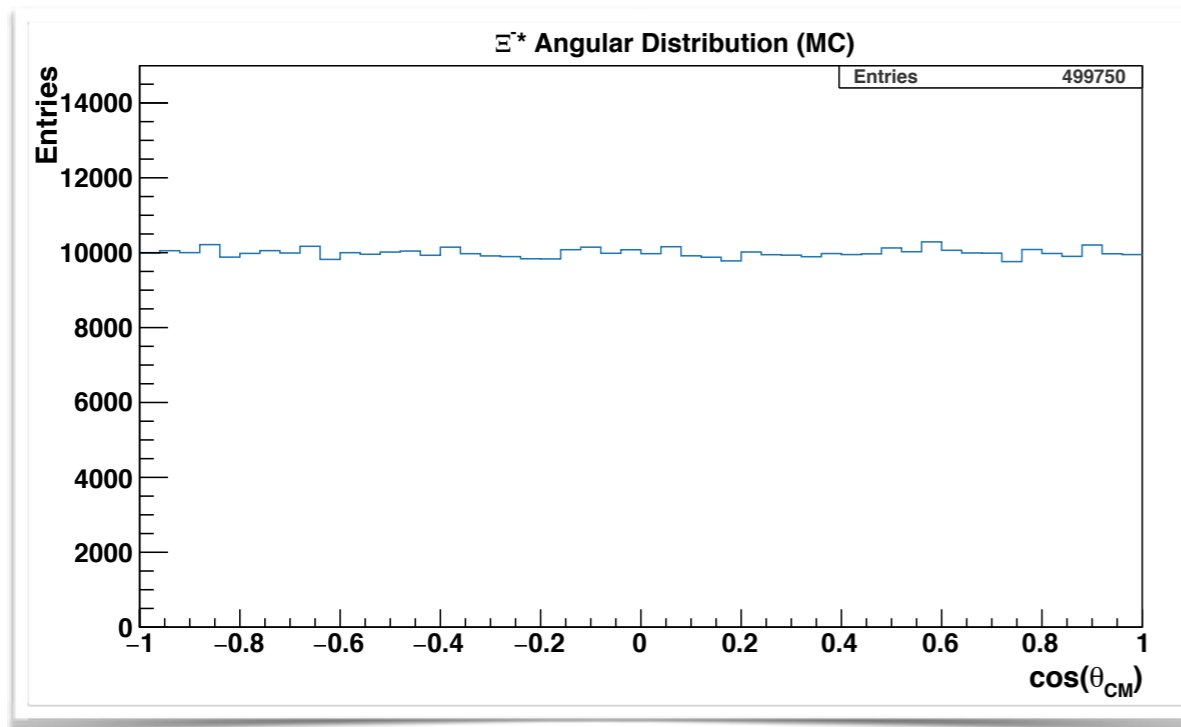
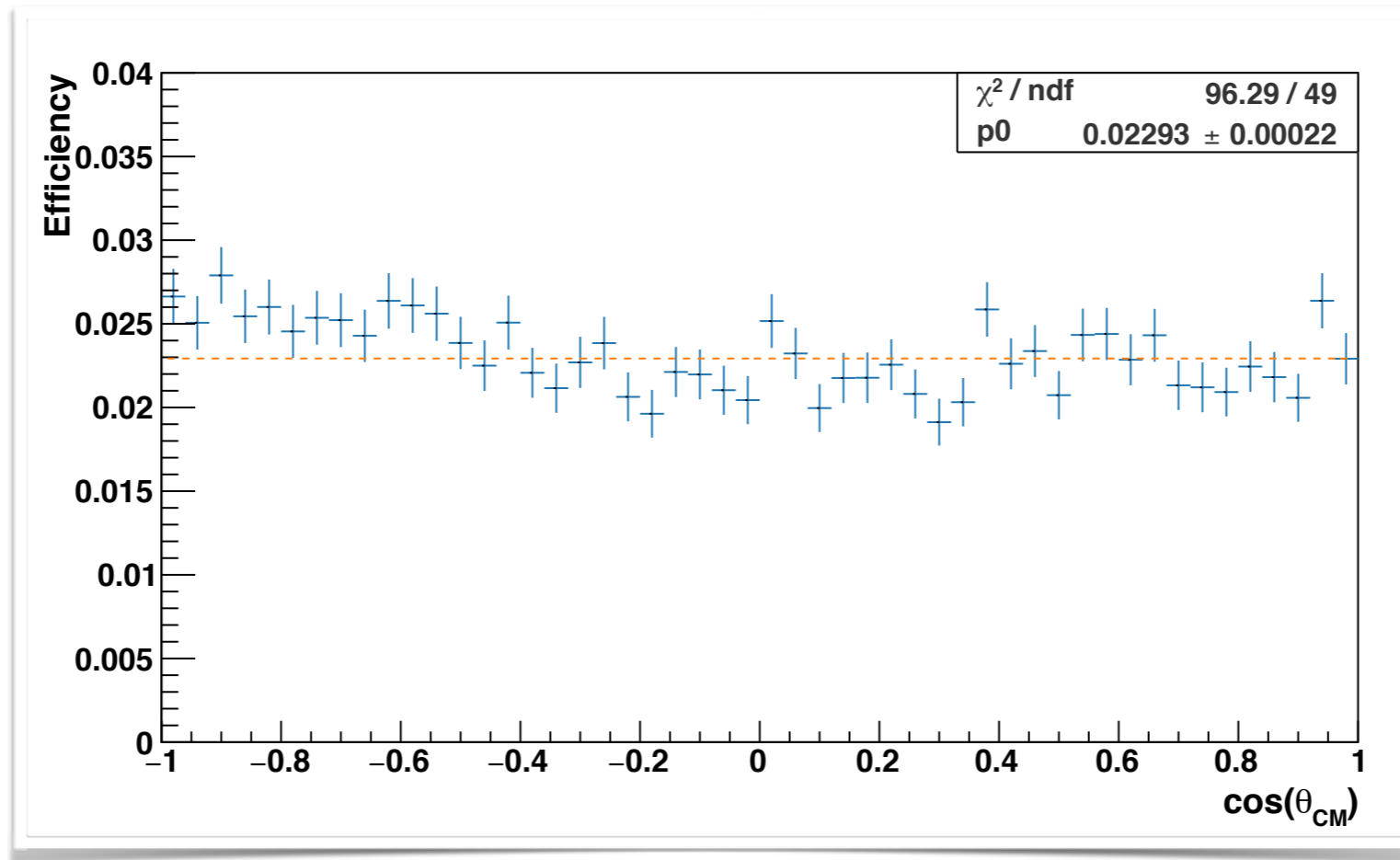
Systematic Effect of Momentum Res.



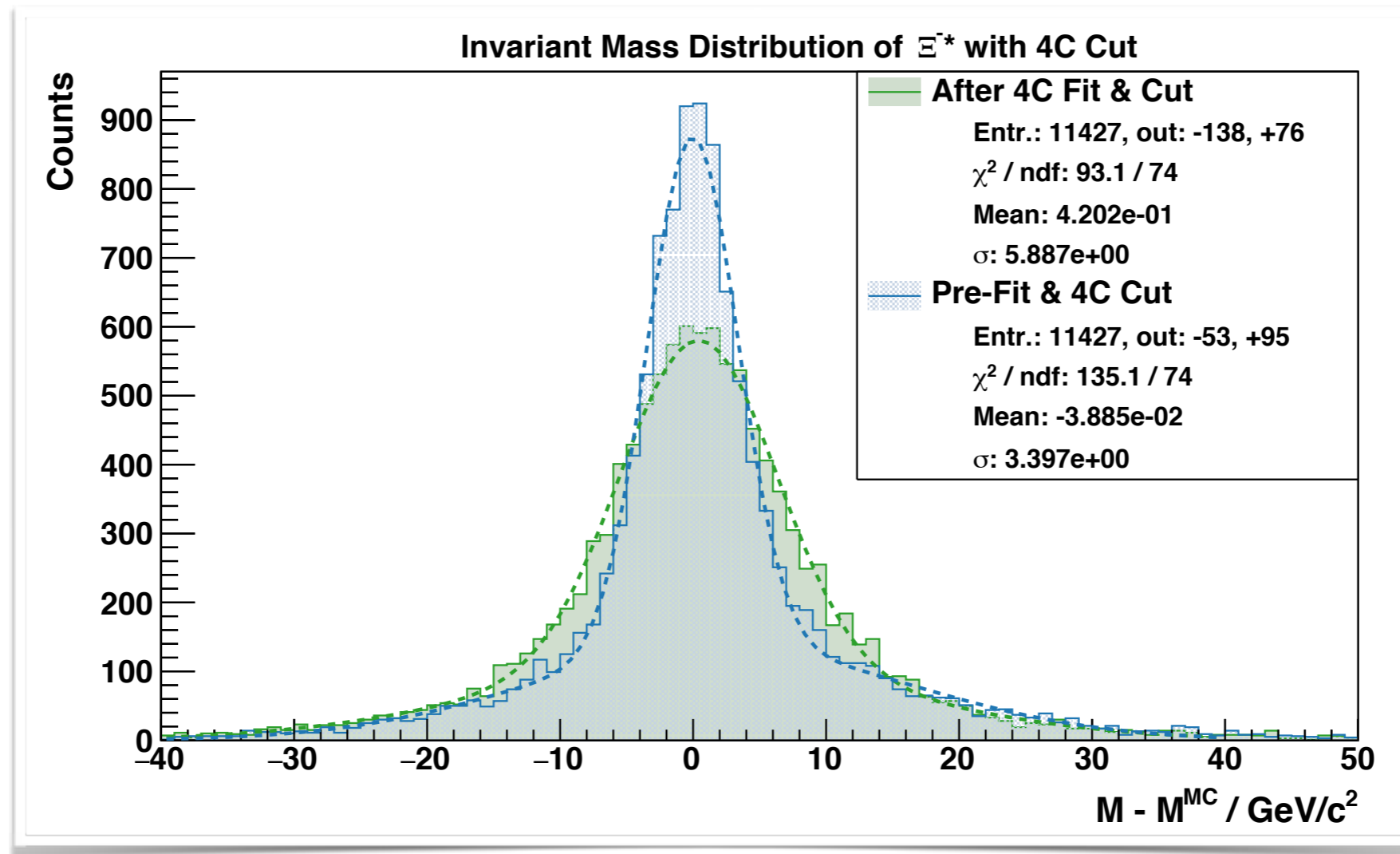
$\Xi^+ \Xi^-$ System — Momentum Distributions



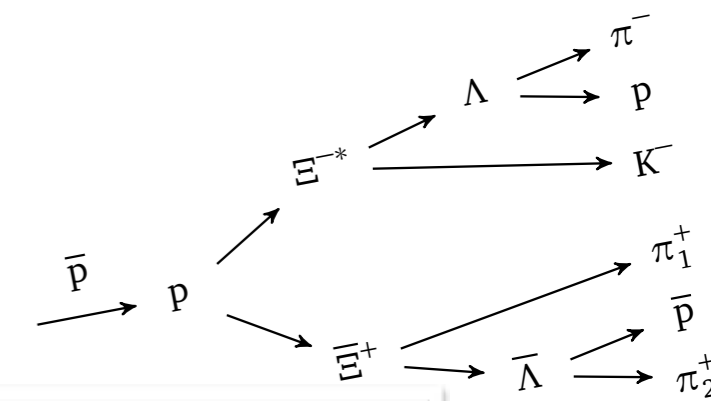
Ξ^- Reconstruction Efficiency



Ξ^- Mass Distribution after 4C Fit



Ξ^- and $\Xi^+\Xi^-$ System Optimization



Ξ^{-*}

Cut Parameter	Unit	Condition	$N_{\Xi^{-*},\text{sig}} / \%$ (176,885)	$N_{\Xi^{-*},\text{bkg}} / \%$ (1441 \times B)	S
<i>Only Λ kinematic cuts</i>			100.0	100.0	22,897
POCA($\Lambda\pi^-$): pocaQA	cm	$3.97 < x$	75.8	31.6	35,188
POCA($\Lambda\pi^-$): d_{IP}	cm	$2.36 < x$	80.3	16.1	60,499
ΔE_{CM}	GeV	$1.704 < x < 1.766$	85.5	7.8	93,920
ΔP_{CM}	GeV/c	$0.284 < x < 0.466$	82.5	7.7	89,656
Inclusive (no distance to IP)			61.0	1.80	89,990
Inclusive (all)			58.9	1.67	87,560

$B = 825.6$

$\Xi^{-*}\Xi^+$ System

Cut Parameter	$N_{\text{sig}} / \%$ (41,614)	$N_{\text{bkg}} / \%$ (20 \times B)	S
<i>Only $\Lambda, \bar{\Lambda}$ kinematic cuts</i>	100.0	100.0	25,662
4C cut: $\text{prob}(\chi^2)_{4\text{C}} > 0.01$	26.5	15.00	8142
4C cut + cuts on Ξ^{-*}	17.7	10.00	5441
4C cut + cuts on Ξ^+	12.1	5.00	4019
All cuts	9.6	5.00	3034

$B = 1293$