Search for $\eta_c \to p k^- \bar{\Lambda}$+c.c. decay

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Outline

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2. **Analysis**
3. **Reconstruct Λ(Λ → pπ-)**
4. **Reconstruct η_c(η_c→pk$^-$$\bar{\Lambda}$)**

Motivation

Recently, the decay channel $\eta_c \to pK^-\bar{\Lambda}$ has been reported in Belle, with the corresponding branching fractions $B(\eta_c \to pK^-\bar{\Lambda}) = (2.9^{+0.4}_{-0.3} \pm 0.4) \times 10^{-3}$.

We perform the analysis to confirm and improve the result.

Total J/Ψ number N=6 Billion

Efficiency ε=17.7%

We expect to observe approximately 52000 η_c events, σ<1%.

Total Branching Fractions of η_c observed

$$\Gamma_{observed}/\Gamma=(63.9227\pm4.5931)\%$$

Decays involving hadronic resonances

Γ_1	$\eta'(958)\pi\pi$	$(4.1\pm1.7)\%$		1323
Γ_2	$\rho\rho$	$(1.8\pm0.5)\%$		1275
Γ_3	$K^*(892)^0K^-\pi^+$ + c.c.	$(2.0\pm0.7)\%$		1278
Γ_4	$K^*(892)\overline{K}^*(892)$	$(7.1\pm1.3)\times10^{-3}$		1196
Γ_5	$K^*(892)^0\overline{K}^*(892)^0\pi^+\pi^-$	$(1.1\pm0.5)\%$		1073
Γ_6	ϕK^+K^-	$(2.9\pm1.4)\times10^{-3}$		1104
Γ_7	$\phi\phi$	$(1.79\pm0.20)\times10^{-3}$		1089
Γ_8	$\phi 2(\pi^+\pi^-)$	$<4\times10^{-3}$	CL=90%	1251
Γ_9	$a_0(980)\pi$	$<2\%$	CL=90%	1327
Γ_{10}	$a_2(1320)\pi$	$<2\%$	CL=90%	1196
Γ_{11}	$K^*(892)\overline{K}$ + c.c.	$<1.28\%$	CL=90%	1310
Γ_{12}	$f_2(1270)\eta$	$<1.1\%$	CL=90%	1145
Γ_{13}	$\omega\omega$	$<3.1\times10^{-3}$	CL=90%	1270
Γ_{14}	$\omega\phi$	$<2.5\times10^{-4}$	CL=90%	1185
Γ_{15}	$f_2(1270)f_2(1270)$	$(9.8\pm2.5)\times10^{-3}$		774
Γ_{16}	$f_2(1270)f_2'(1525)$	$(9.8\pm3.2)\times10^{-3}$		513
Γ_{17}	$f_0(980)\eta$	seen		1264
Γ_{18}	$f_0(1500)\eta$	seen		1026
Γ_{19}	$f_0(2200)\eta$	seen		497
Γ_{20}	$a_0(980)\pi$	seen		1327
Γ_{21}	$a_0(1320)\pi$	seen		
Γ_{22}	$a_0(1450)\pi$	seen		1123
Γ_{23}	$a_0(1950)\pi$	seen		860
Γ_{24}	$a_2(1950)\pi$	not seen		
Γ_{25}	$K_0^*(1430)\overline{K}$	seen		
Γ_{26}	$K_2^*(1430)\overline{K}$	seen		
Γ_{27}	$K_0^*(1950)\overline{K}$	seen		

Decays into stable hadrons

Γ_{28}	$K\overline{K}\pi$	$(7.3\pm0.5)\%$		1381
Γ_{29}	$K\overline{K}\eta$	$(1.36\pm0.16)\%$		1265
Γ_{30}	$\eta\pi^+\pi^-$	$(1.7\pm0.5)\%$		1428
Γ_{31}	$\eta 2(\pi^+\pi^-)$	$(4.4\pm1.3)\%$		1386
Γ_{32}	$K^+K^-\pi^+\pi^-$	$(6.9\pm1.1)\times10^{-3}$		1345
Γ_{33}	$K^+K^-\pi^+\pi^-\pi^0$	$(3.5\pm0.6)\%$		1304
Γ_{34}	$K^0K^-\pi^+\pi^-\pi^+$ +c.c.	$(5.6\pm1.5)\%$		
Γ_{35}	$K^+K^-2(\pi^+\pi^-)$	$(7.5\pm2.4)\times10^{-3}$		1254
Γ_{36}	$2(K^+K^-)$	$(1.47\pm0.31)\times10^{-3}$		1055
Γ_{37}	$\pi^+\pi^-\pi^0$	$<5\times10^{-4}$	CL=90%	1476
Γ_{38}	$\pi^+\pi^-\pi^0\pi^0$	$(4.7\pm1.0)\%$		1460
Γ_{39}	$2(\pi^+\pi^-)$	$(9.7\pm1.2)\times10^{-3}$		1459
Γ_{40}	$2(\pi^+\pi^-\pi^0)$	$(17.4\pm3.3)\%$		1409
Γ_{41}	$3(\pi^+\pi^-)$	$(1.8\pm0.4)\%$		1407
Γ_{42}	$p\overline{p}$	$(1.52\pm0.16)\times10^{-3}$		1160
Γ_{43}	$p\overline{p}\pi^0$	$(3.6\pm1.3)\times10^{-3}$		1101
Γ_{44}	$\Lambda\overline{\Lambda}$	$(1.09\pm0.24)\times10^{-3}$		991
Γ_{45}	$\Sigma^+\overline{\Sigma}^-$	$(2.1\pm0.6)\times10^{-3}$		901
Γ_{46}	$\Xi^-\overline{\Xi}^+$	$(9.0\pm2.6)\times10^{-4}$		692
Γ_{47}	$\pi^+\pi^-p\overline{p}$	$(5.3\pm1.8)\times10^{-3}$		1027

Radiative decays

Γ_{48}	$\gamma\gamma$	$(1.57\pm0.12)\times10^{-4}$		1492

Charge conjugation (C), Parity (P),Lepton family number (LF) violating modes

Γ_{49}	$\pi^+\pi^-$	$<1.1\times10^{-4}$	CL=90%	1485
Γ_{50}	$\pi^0\pi^0$	$<4\times10^{-5}$	CL=90%	1486
Γ_{51}	K^+K^-	$<6\times10^{-4}$	CL=90%	1408
Γ_{52}	$K_S^0K_S^0$	$<3.1\times10^{-4}$	CL=90%	1406

Analysis

1. Analysis Environment: BOSS 6.6.4.p01
2. MC: 0.46M MC samples generated at $\sqrt{s}$= 3.097 GeV
3. Firstly, we reconstruct the Λ by the decay mode $\Lambda \rightarrow p\pi^-$
4. Secondly, we reconstruct the η_c by the decay mode $\eta_c \rightarrow pk^-\bar{\Lambda}$

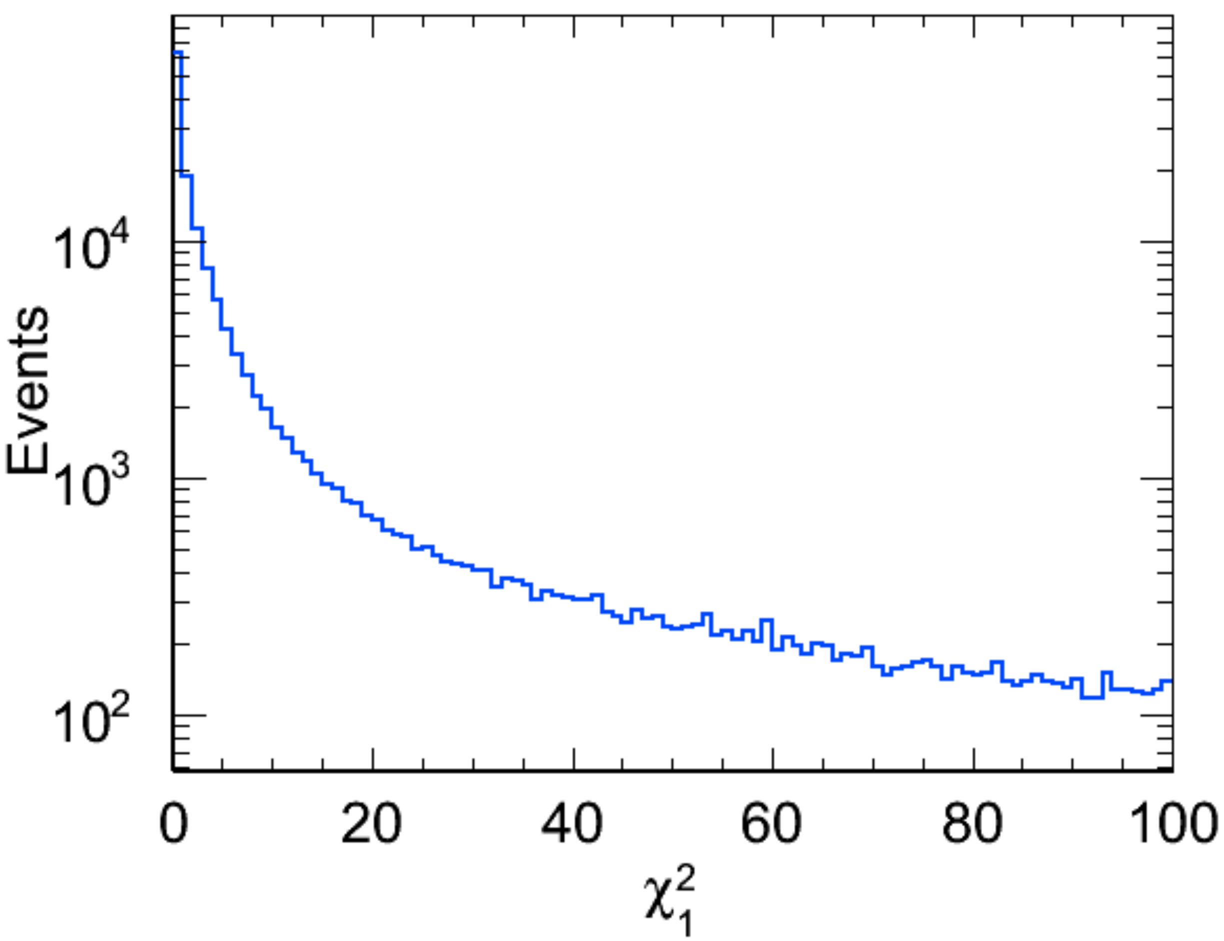
Reconstruct Λ(Λ → pπ-)

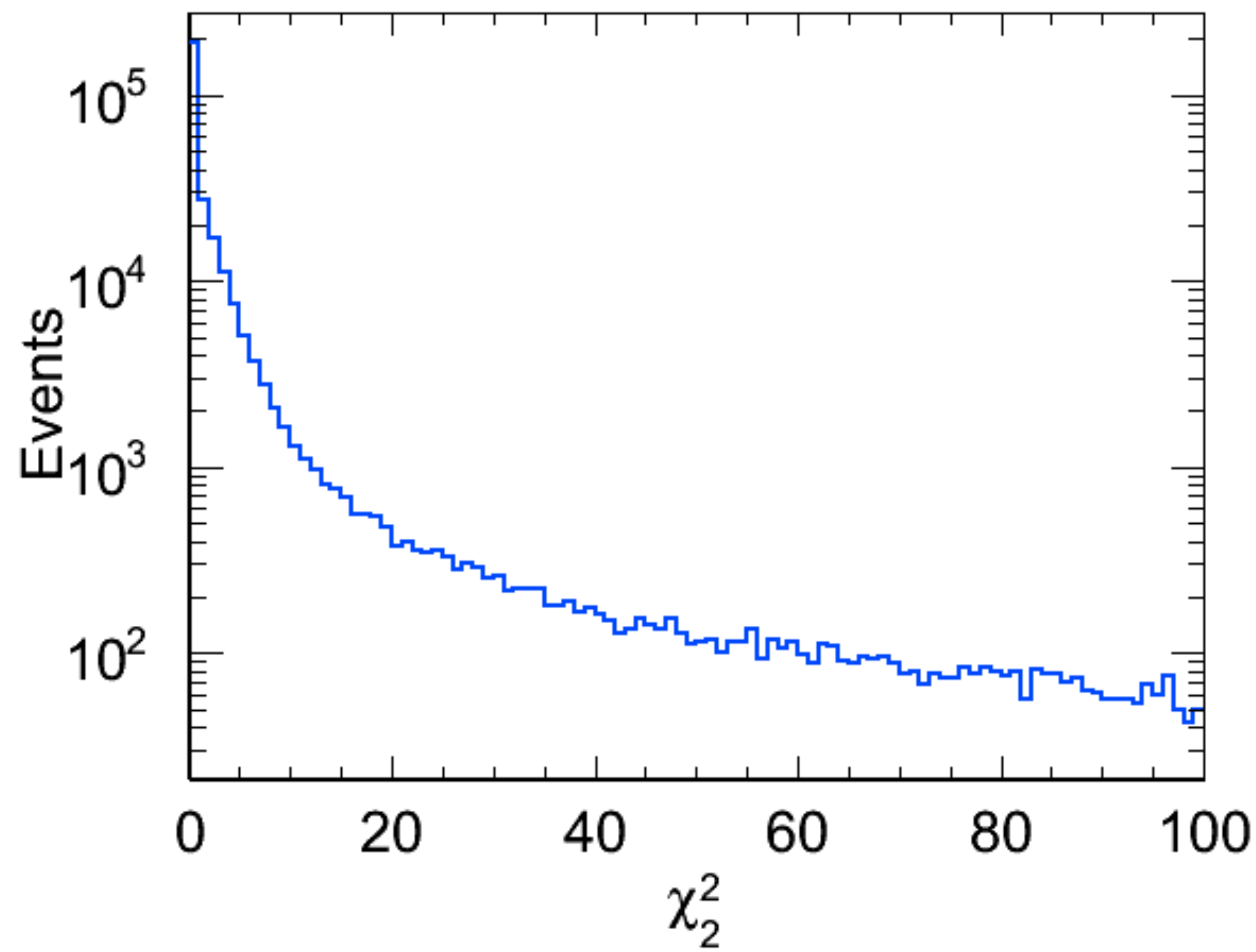
1. Good charged track:

   Distance of the track from IP in z direction: $|R_Z| < 20$ cm.

   The polar angle of the track: $|\cos\theta| < 0.93$.

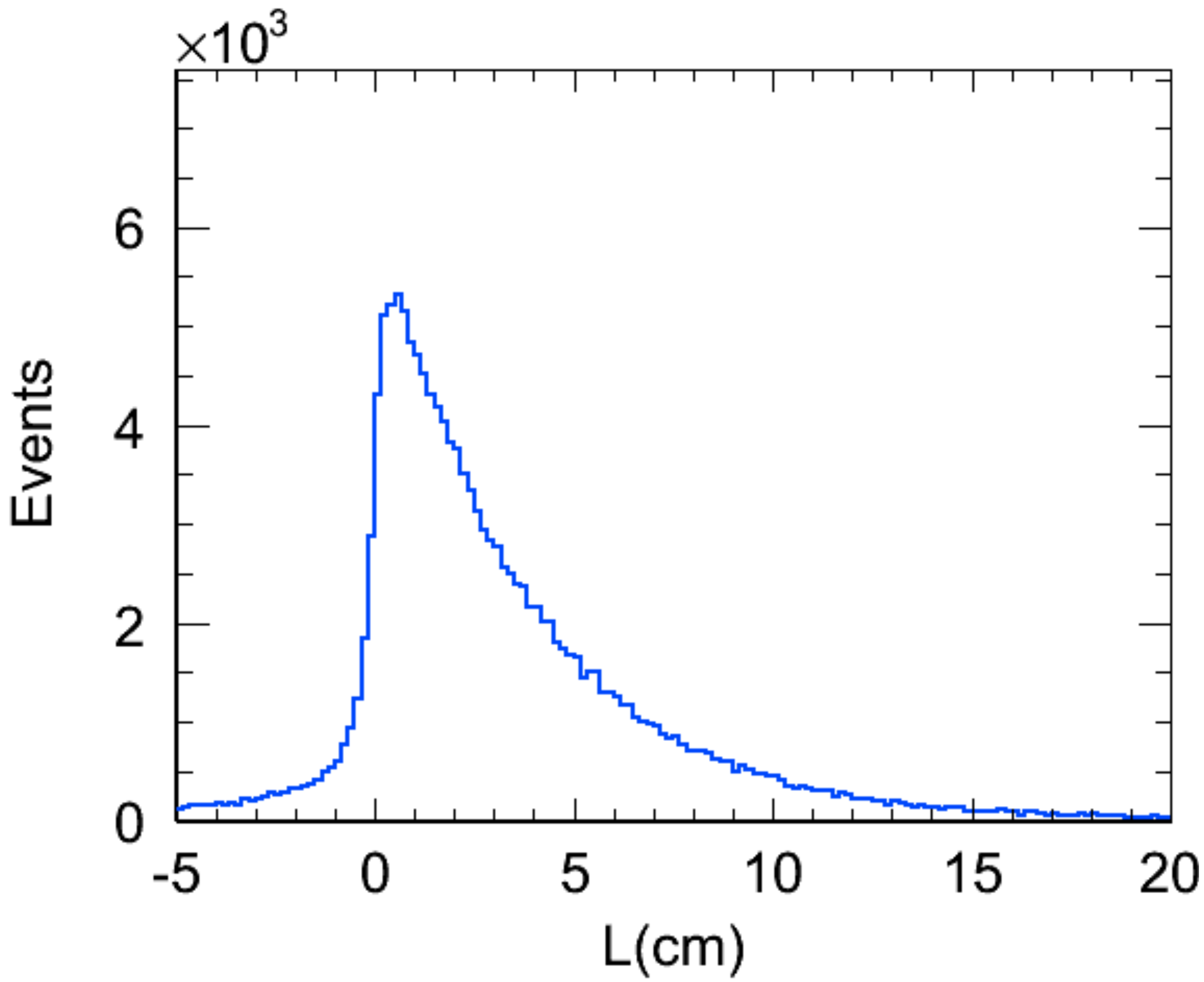
2. Proton PID: prob(p) > 0, prob(p) > prob(π), prob(p) > prob(K).
3. No pion PID.
4. χ^2 of the primary vertex fit: $\chi^2_1 < 100$.
5. χ^2 of the secondary vertex fit: $\chi^2_2 < 100$.

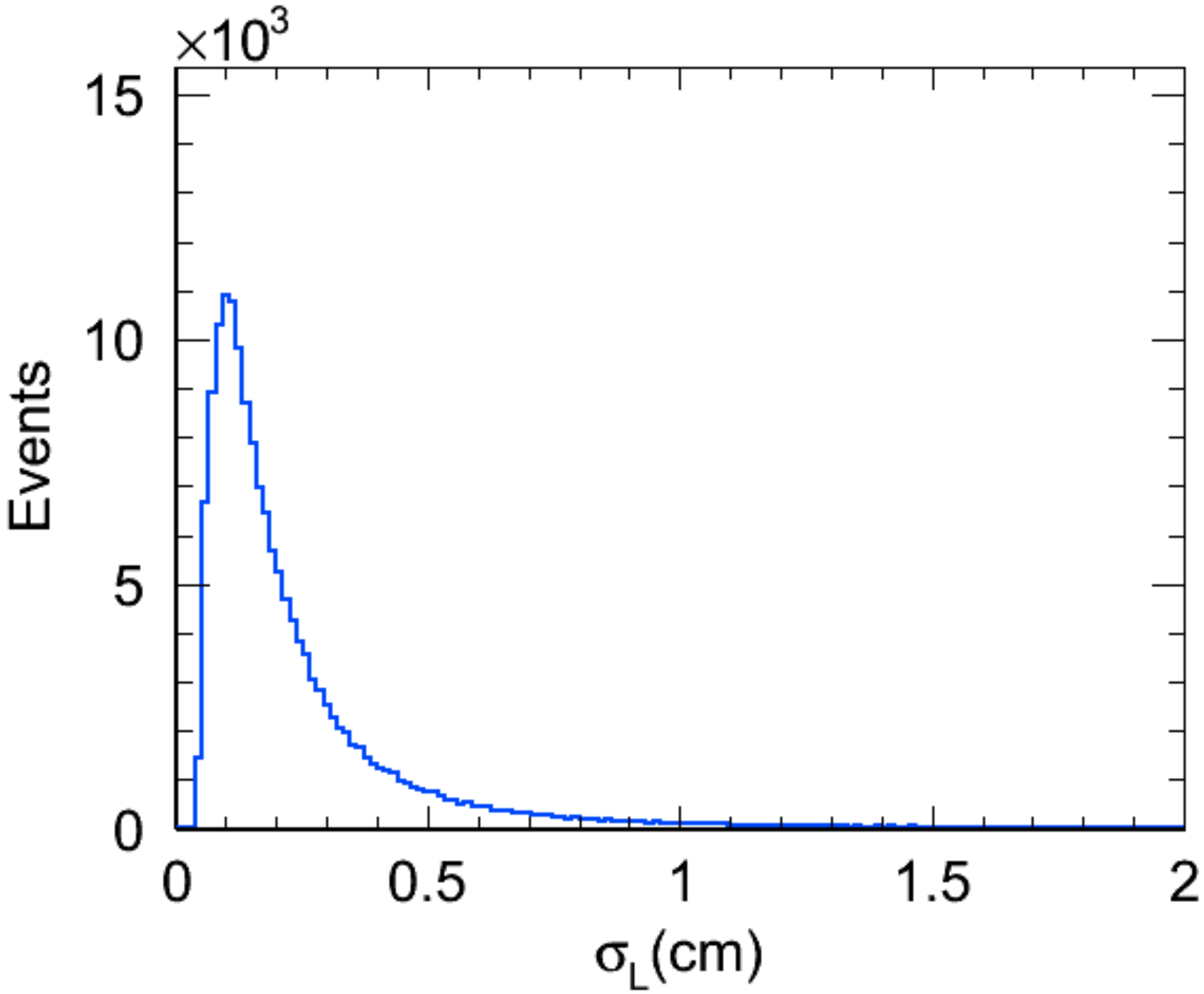




Reconstruct Λ(Λ → pπ-)

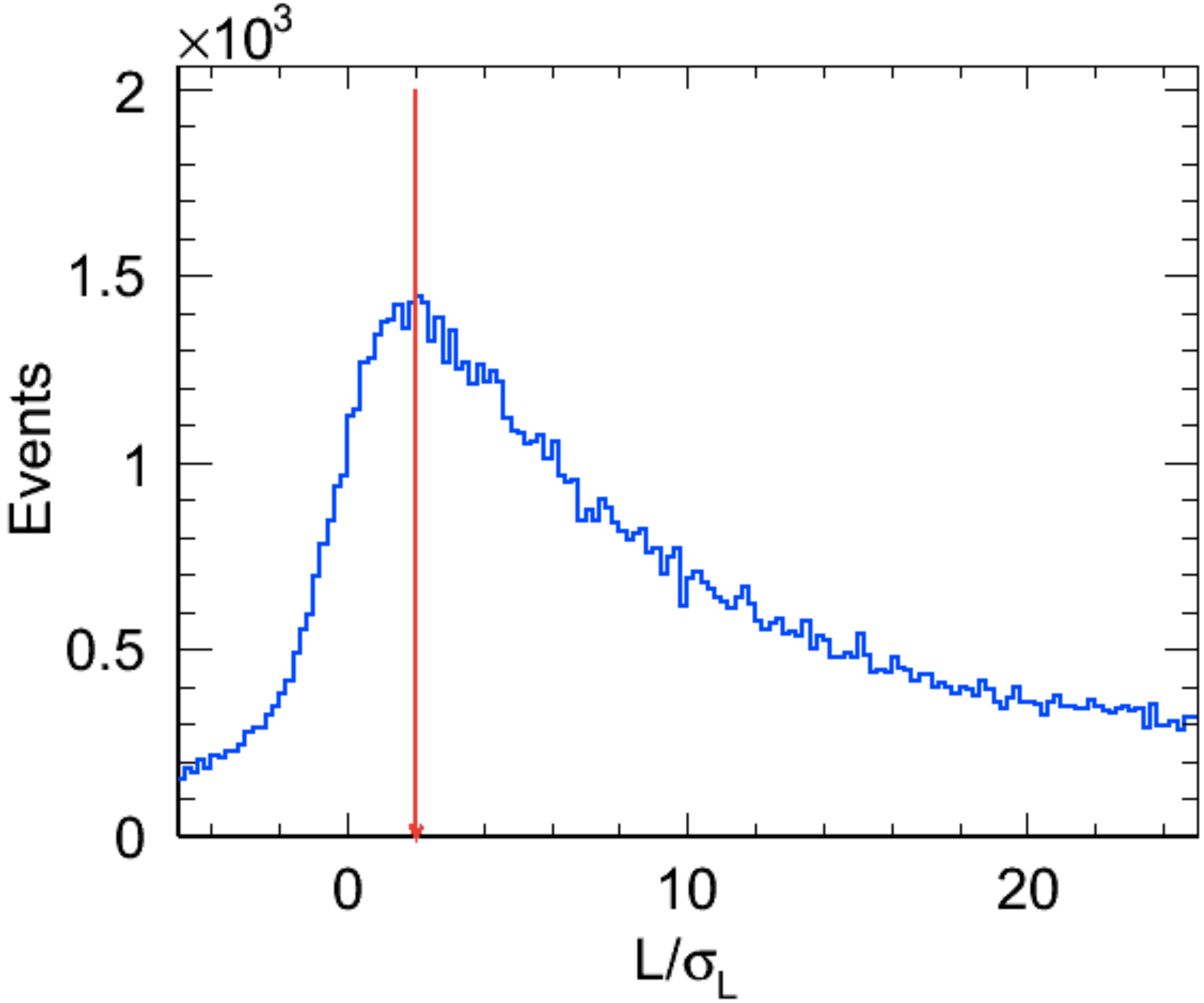
flight length: L +/- σ_L:





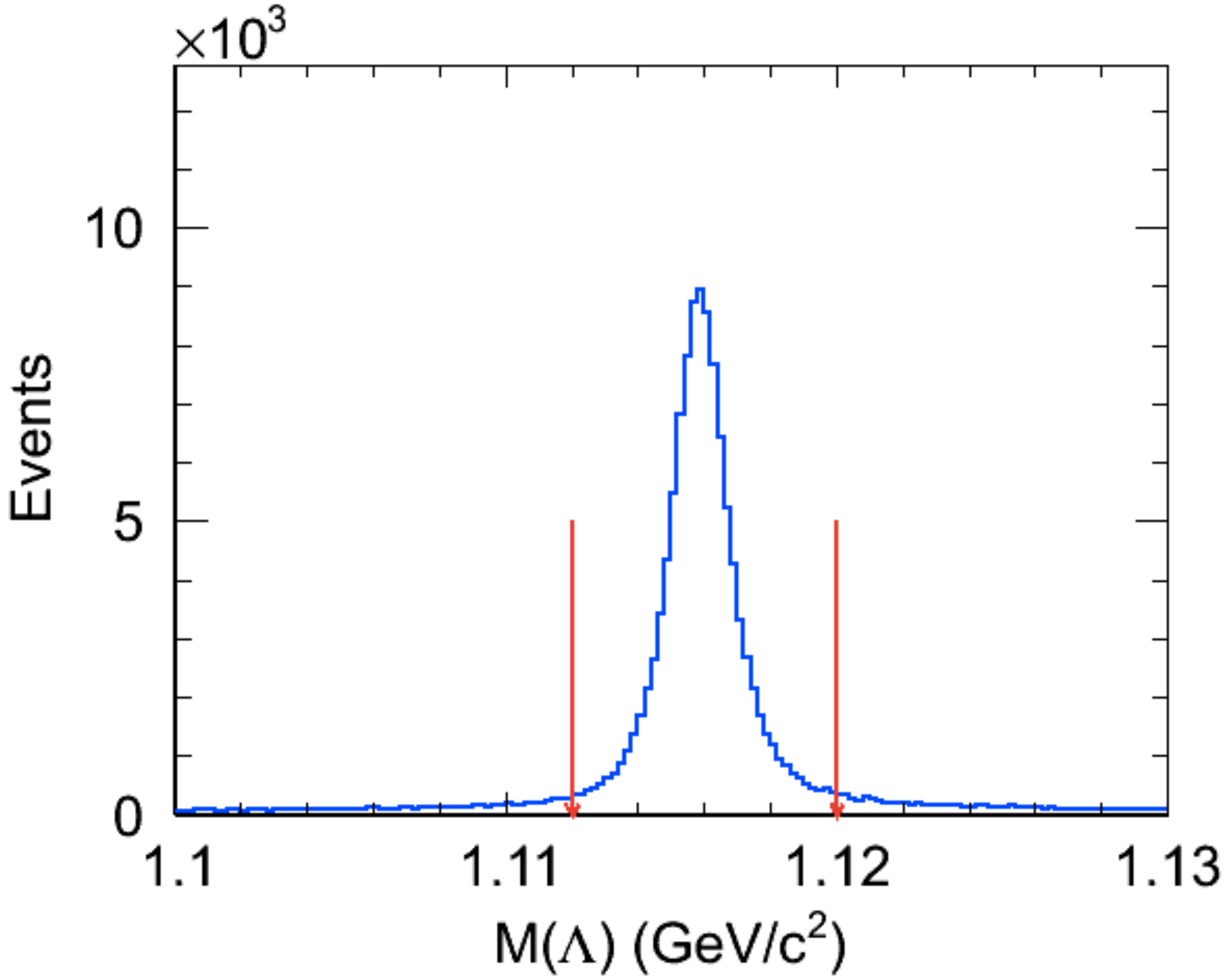
Reconstruct Λ(Λ → pπ-)

L/σ_L of the secondary vertex fit: $L/\sigma_L > 2$



Reconstruct $\Lambda(\Lambda \to p\pi^-)$

Invariant mass of Λ candidates: $M(\Lambda) \in [1.112, 1.120]$ GeV/c^2



Reconstruct $\eta_c(\eta_c \to pk^-\bar{\Lambda})$

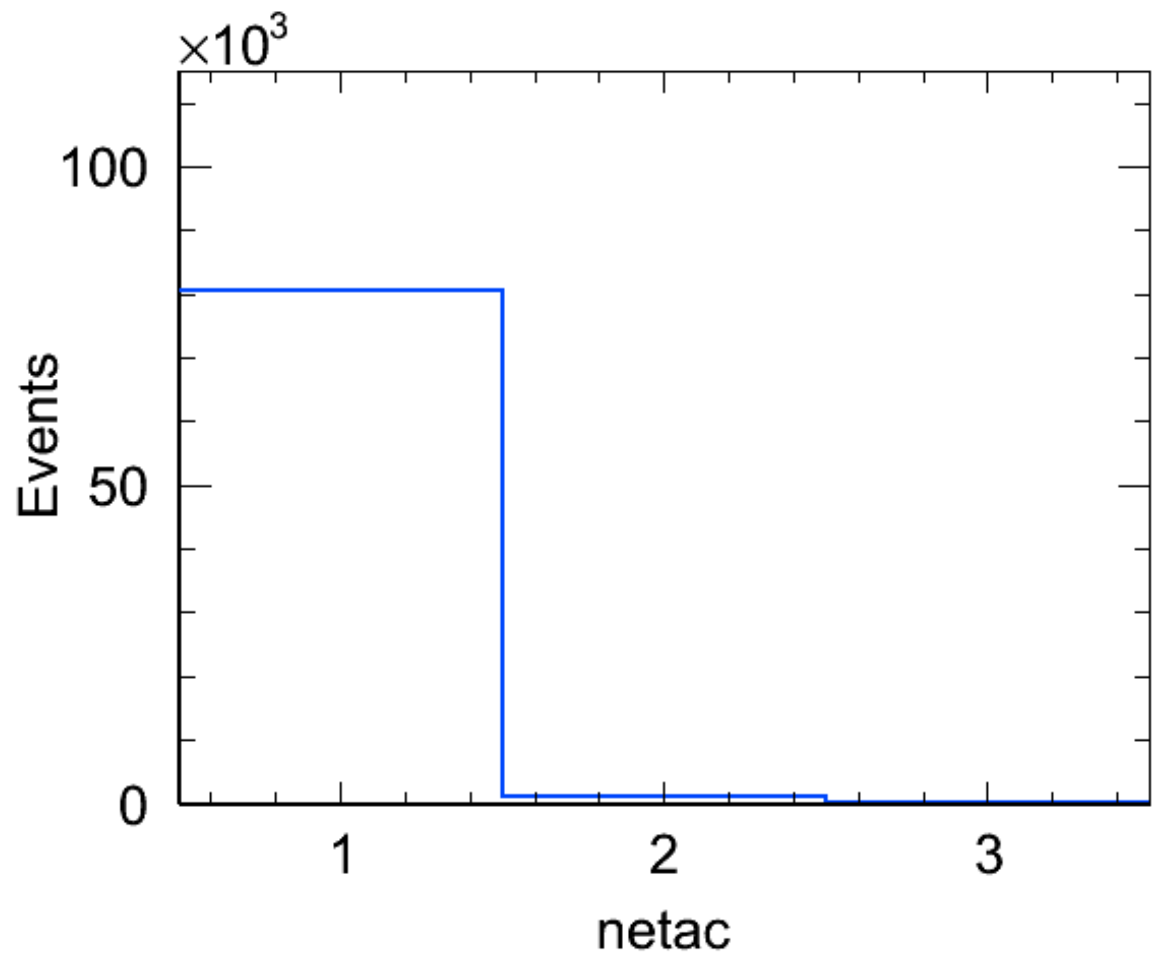
1. Good charged track:

   Distance of the track from IP in z direction: $|R_Z| < 10$ cm.

   Distance of the track from IP in x-y direction: $|R_{xy}| < 1$ cm.

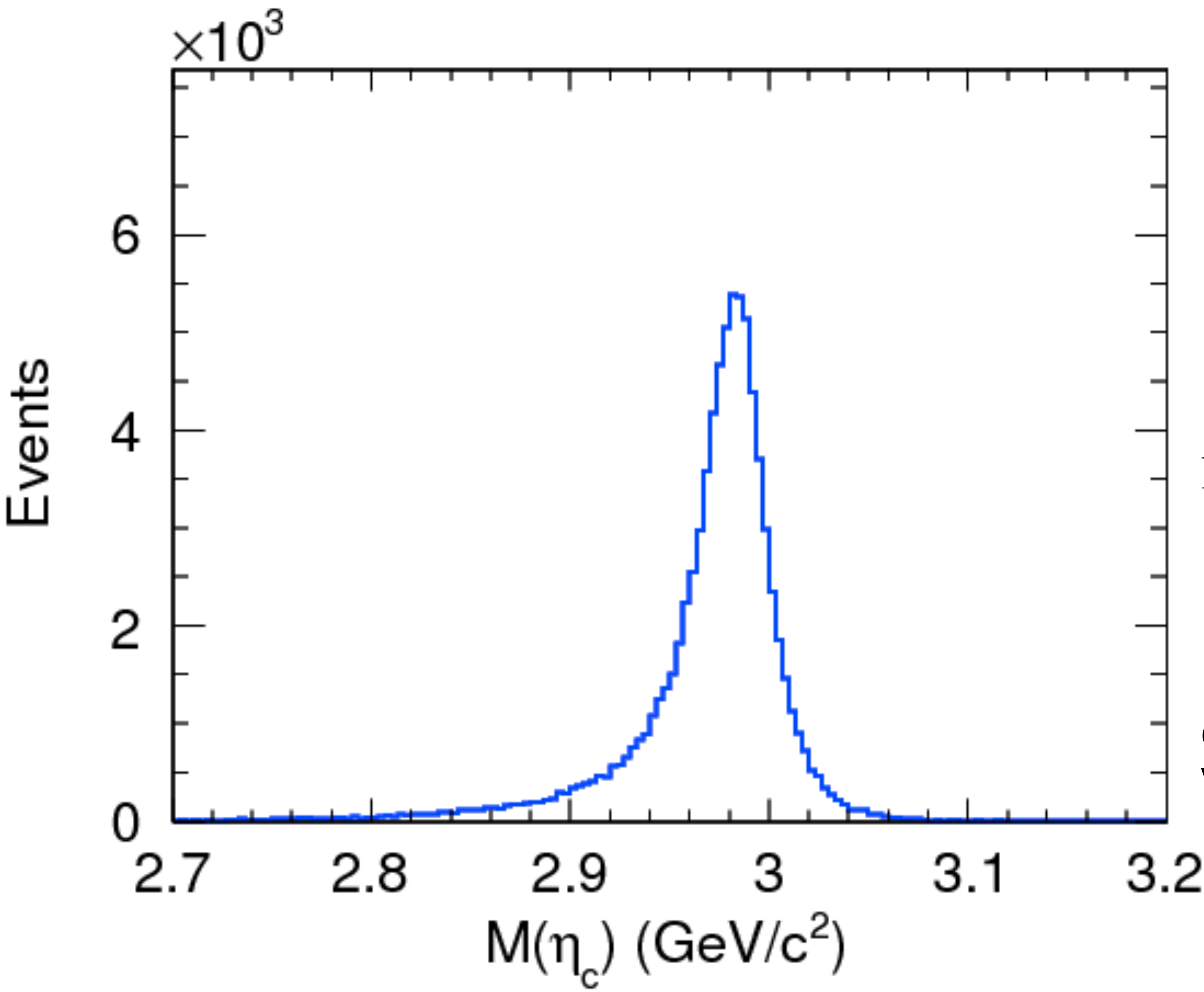
   The polar angle of the track: $|\cos\theta| < 0.93$.

2. Proton PID: prob(p) > 0, prob(p) > prob(π), prob(p) > prob(K).
3. Kaon PID: prob(K)>0, prob(K)>prob(p), prob(K)>prob(π)
4. $M(\Lambda) \in (1.111, \ 1.120)$ Gev/c^2



Reconstruct $\eta_c(\eta_c \rightarrow pk^-\bar{\Lambda})$

Invariant mass of η_c candidates: $M(\eta_c)$



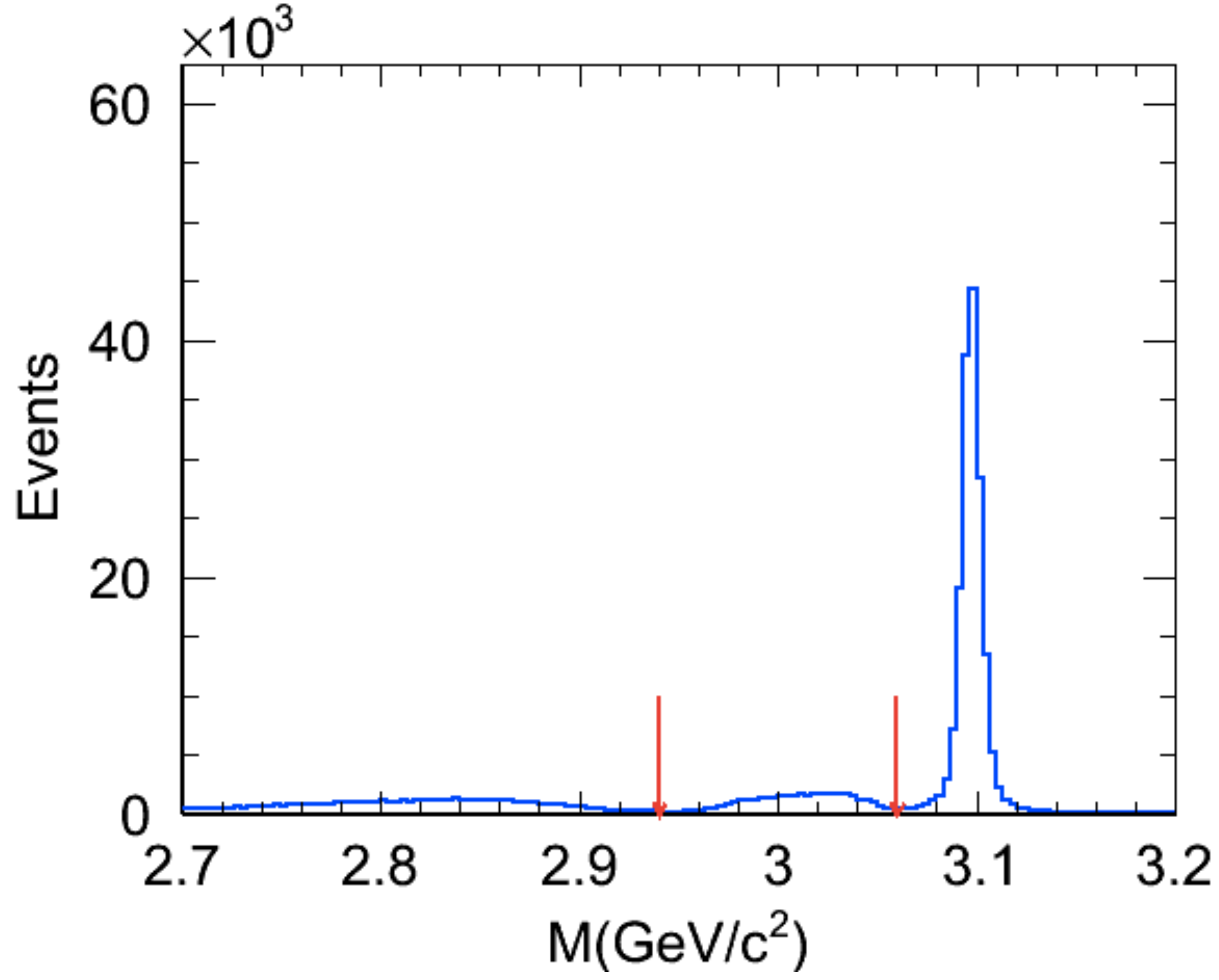
$J/\Psi \rightarrow \gamma\eta_c$ Decay width:

$$\Gamma_{J/\psi \rightarrow \eta_c \gamma} = \frac{16}{3} \alpha e_c^2 \frac{k_\gamma^3}{M_{J/\psi}^2} [1 + C_F \frac{\alpha_s(M_{J/\psi}/2)}{\pi} - \frac{2}{3}(C_F \alpha_s(p_{J/\psi}))^2]$$

Given by Nora Brambilla, Yu Jia, and Antonio Vairo Phy. Rev. D 73, 054005 (2006)

Reconstruct η_c($\eta_c \to pk^-\bar{\Lambda}$)

Inclusive MC result:



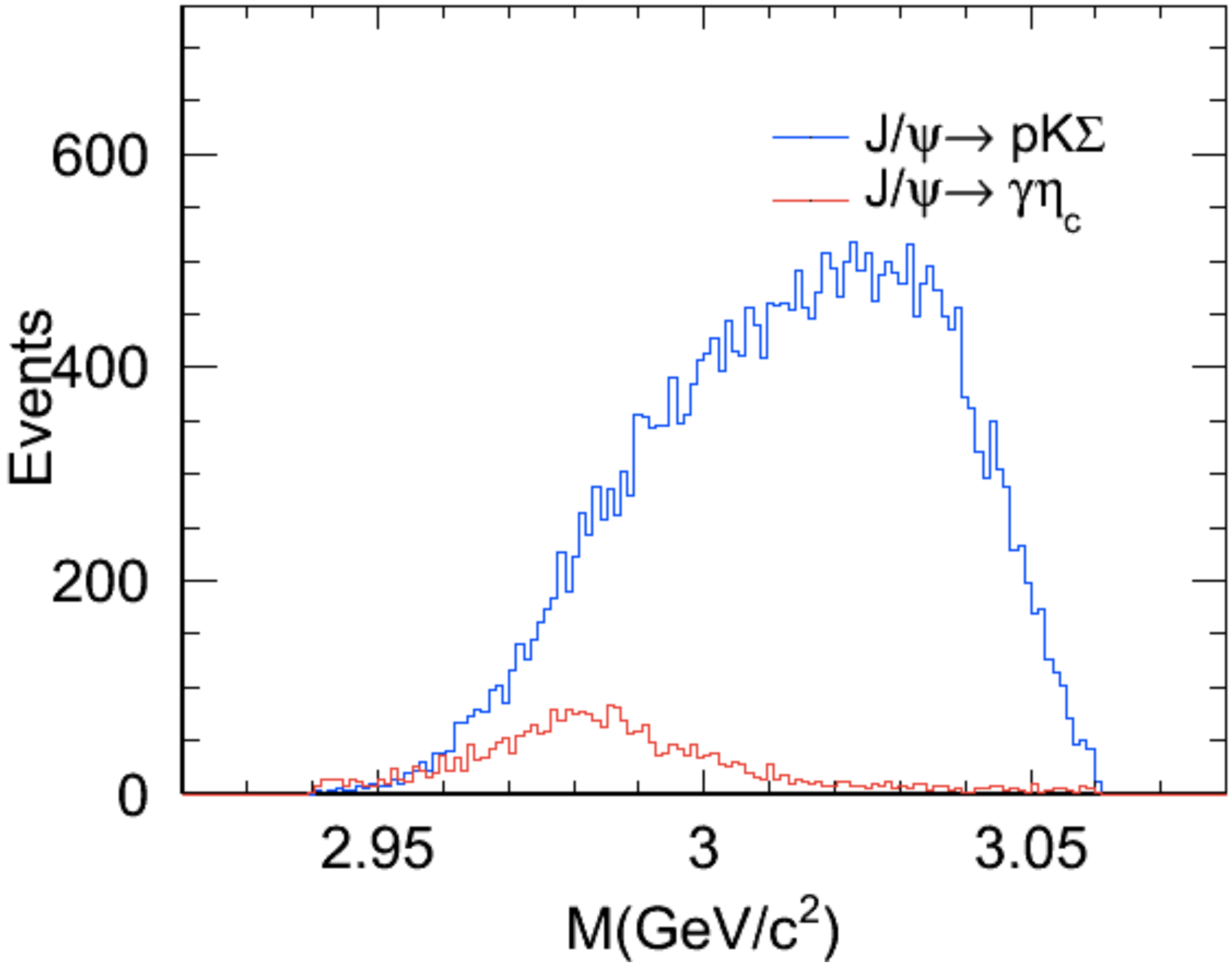
Reconstruct $\eta_c(\eta_c \to pk^-\bar{\Lambda})$

All the processes in $M \in [2.94, 3.06]$

No.	decay chain	final states	iTopology	nEvt	nTot
0	$J/\psi \to pK^-\bar{\Sigma}^0, \bar{\Sigma}^0 \to \gamma\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\bar{p}K^-\pi^+\gamma p$	0	26233	26233
1	$J/\psi \to \Sigma^0 K^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to p\pi^-$	$\pi^-\bar{p}\gamma pK^+$	1	3194	29427
2	$J/\psi \to \eta_c\gamma, \eta_c \to \Lambda K^+\bar{p}, \Lambda \to p\pi^-$	$\pi^-\bar{p}\gamma pK^+$	2	1500	30927
3	$J/\psi \to \eta_c\gamma, \eta_c \to pK^-\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\bar{p}K^-\pi^+\gamma p$	5	1353	32280
4	$J/\psi \to \Lambda K^+\bar{p}, \Lambda \to p\pi^-$	$\pi^-\bar{p}pK^+$	4	850	33130
5	$J/\psi \to pK^-\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\bar{p}K^-\pi^+p$	3	752	33882
6	$J/\psi \to \Lambda K^+\gamma\bar{p}, \Lambda \to p\pi^-$	$\pi^-\bar{p}\gamma pK^+$	8	199	34081
7	$J/\psi \to p\gamma K^-\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\bar{p}K^-\pi^+\gamma p$	16	175	34256
8	$J/\psi \to \Lambda K^+\gamma_{FSR}\bar{p}, \Lambda \to p\pi^-$	$\pi^-\bar{p}pK^+$	18	164	34420
9	$J/\psi \to \Lambda\pi^+\bar{\Sigma}^-, \Lambda \to p\pi^-, \bar{\Sigma}^- \to \pi^0\bar{p}$	$\pi^-\bar{p}\pi^0\pi^+p$	17	130	34550
10	$J/\psi \to p\gamma_{FSR}K^-\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\bar{p}K^-\pi^+p$	9	128	34678
11	$J/\psi \to pK^-\bar{\Sigma}^{*0}, \bar{\Sigma}^{*0} \to \pi^0\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\bar{p}K^-\pi^0\pi^+p$	28	114	34792
12	$J/\psi \to \Sigma^+\pi^-\bar{\Lambda}, \Sigma^+ \to p\pi^0, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^-\bar{p}\pi^0\pi^+p$	12	111	34903
13	$J/\psi \to \Xi^-\bar{\Xi}^+, \Xi^- \to \Lambda\pi^-, \bar{\Xi}^+ \to \pi^+\bar{\Lambda}, \Lambda \to p\pi^-, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^-\pi^-\bar{p}\pi^+\pi^+p$	13	68	34971
14	$J/\psi \to \Sigma^+\bar{\Sigma}^{*-}, \Sigma^+ \to p\pi^0, \bar{\Sigma}^{*-} \to \pi^-\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^-\bar{p}\pi^0\pi^+p$	26	67	35038
15	$J/\psi \to \Lambda\gamma\bar{\Lambda}, \Lambda \to p\pi^-, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^-\bar{p}\pi^+\gamma p$	10	56	35094
16	$J/\psi \to p\pi^+\pi^0\pi^-\bar{p}$	$\pi^-\bar{p}\pi^0\pi^+p$	22	50	35144
17	$J/\psi \to pK^{*-}\bar{\Lambda}, K^{*-} \to \pi^0 K^-, \bar{\Lambda} \to \pi^+\bar{p}$	$\bar{p}K^-\pi^0\pi^+p$	74	41	35185
18	$J/\psi \to p\gamma_{FSR}K^-\bar{\Sigma}^0, \bar{\Sigma}^0 \to \gamma\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\bar{p}K^-\pi^+\gamma p$	27	39	35224
19	$J/\psi \to \Lambda K^+\pi^0\bar{p}, \Lambda \to p\pi^-$	$\pi^-\bar{p}\pi^0 pK^+$	11	34	35258
20	$J/\psi \to \Sigma^{*+}\bar{\Sigma}^{*-}, \Sigma^{*+} \to \Lambda\pi^+, \bar{\Sigma}^{*-} \to \pi^-\bar{\Lambda}, \Lambda \to p\pi^-, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^-\pi^-\bar{p}\pi^+\pi^+p$	47	31	35289
21	$J/\psi \to \Delta^+K^-\bar{\Lambda}, \Delta^+ \to p\pi^0, \bar{\Lambda} \to \pi^+\bar{p}$	$\bar{p}K^-\pi^0\pi^+p$	64	28	35317
22	$J/\psi \to \Sigma^{*-}\bar{\Sigma}^{*+}, \Sigma^{*-} \to \Lambda\pi^-, \bar{\Sigma}^{*+} \to \pi^+\bar{\Lambda}, \Lambda \to p\pi^-, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^-\pi^-\bar{p}\pi^+\pi^+p$	52	26	35343
23	$J/\psi \to \Lambda K^{*+}\bar{p}, \Lambda \to p\pi^-, K^{*+} \to K^+\pi^0$	$\pi^-\bar{p}\pi^0 pK^+$	21	26	35369
24	$J/\psi \to p\pi^+\pi^-\bar{p}$	$\pi^-\bar{p}\pi^+p$	65	23	35392
25	$J/\psi \to \Lambda K^+\bar{\Delta}^+, \Lambda \to p\pi^-, \bar{\Delta}^+ \to \pi^0\bar{p}$	$\pi^-\bar{p}\pi^0 pK^+$	30	21	35413
26	$J/\psi \to \Delta^{++}\pi^-\bar{\Delta}^+, \Delta^{++} \to p\pi^+, \bar{\Delta}^+ \to \pi^0\bar{p}$	$\pi^-\bar{p}\pi^0\pi^+p$	66	16	35429
27	$J/\psi \to p\pi^0K^-\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\bar{p}K^-\pi^0\pi^+p$	72	16	35445
28	$J/\psi \to \Delta^+\pi^+\bar{\Delta}^{--}, \Delta^+ \to p\pi^0, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^-\bar{p}\pi^0\pi^+p$	7	16	35461
29	$J/\psi \to \Sigma^{*+}\bar{\Sigma}^-, \Sigma^{*+} \to \Lambda\pi^+, \bar{\Sigma}^- \to \pi^0\bar{p}, \Lambda \to p\pi^-$	$\pi^-\bar{p}\pi^0\pi^+p$	73	15	35476

Table 1:
Search for $\eta_c \to pk^-\bar{\Lambda}$+c.c. decay

Reconstruct $\eta_c(\eta_c \rightarrow pk^- \bar{\Lambda})$



Search for $\eta_c \rightarrow pk^- \bar{\Lambda}$+c.c. decay

Thank you!