PWA of process $e^+e^- \to \pi^0\Lambda\bar{\Lambda}$ at 3.773 GeV

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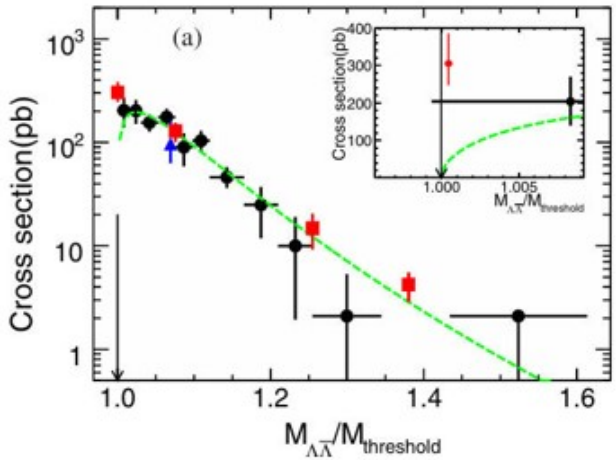
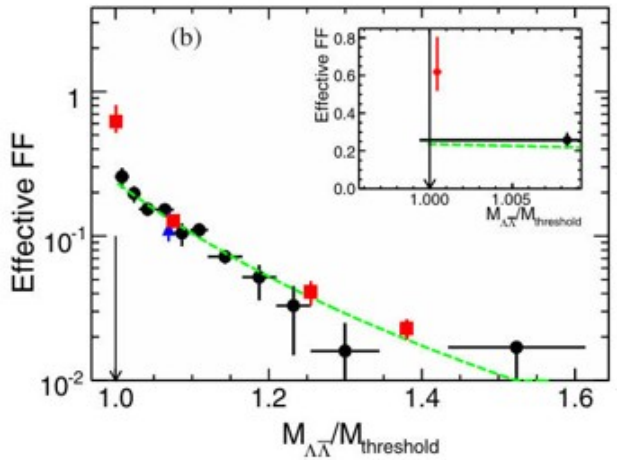
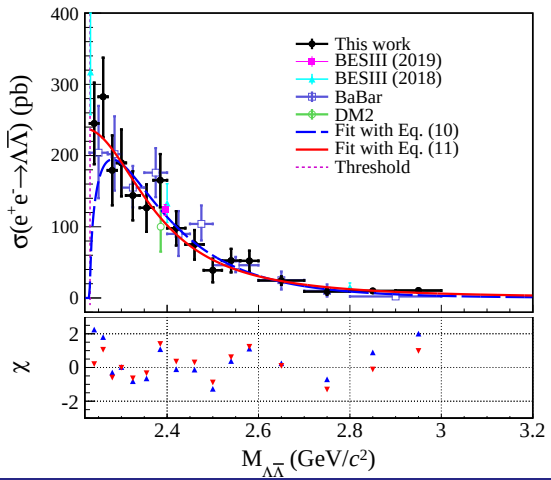
Contents

Motivation I

- BESIII has observed enhancement near the $\Lambda\bar{\Lambda}$ threshold on the cross section spectrum of $e^+e^- \to \Lambda\bar{\Lambda}$ process (Phys.Rev.D 97 (2018) 3, 032013), which was confirmed by the following work via the ISR process $e^+e^- \to \gamma_{\rm ISR}\Lambda\bar{\Lambda}$ (Phys.Rev.D 107 (2023) 7, 072005). However, the reason or original of the enhancement is still not clear.







Motivation II

- Meanwhile, the structures on $\Lambda\bar{\Lambda}$ mass spectrum have been studied a lot with the final state of $X + \Lambda\bar{\Lambda}$ ($X = \gamma, \eta, \phi, \omega$, etc.) by BESIII through the charmonium decay or the direct production by the e^+e^- annihilation.

Table: Possible stuctures found on $\Lambda\bar{\Lambda}$ mass spectrum at BESIII.

Process	Mass (MeV)	Width (MeV)	J(P)	Stage
$\chi_{cJ} \to \phi\Lambda\bar{\Lambda}$	not found	-	-	Published (BAM 682)
$\chi_{cJ} \to \omega\Lambda\bar{\Lambda}$	not found	-	-	Published (BAM 723)
$\chi_{cJ} \to \eta\Lambda\bar{\Lambda}$	not found	-	-	Published (BAM 496)
$\chi_{cJ} \to \eta'\Lambda\bar{\Lambda}$	not found	-	-	Memo review (BAM 951
$J/\psi \to \eta\Lambda\bar{\Lambda}$	not found	-	-	Draft review (BAM 643
$J/\psi \to \gamma\Lambda\bar{\Lambda}$	2285.7, 2587.6, 2267.7, 2291.8	60.6, 239.9, 25.9, 207.3	0(-), 0(-), 0(+), 2(+)	Memo not found
$\psi' \to \phi\Lambda\bar{\Lambda}$	not measured	-	0(-), 0(+)	Group review (doc 1480
$\psi' \to \omega\Lambda\bar{\Lambda}$	not found	-	-	Published (BAM 336)
$\psi' \to \eta\Lambda\bar{\Lambda}$	2290	40	favor 1(-)	Published (BAM 336)
$\psi' \to \eta'\Lambda\bar{\Lambda}$	not found	-	-	Published (BAM658)
$\psi' \to \gamma\Lambda\bar{\Lambda}$	2289, 2617	207, 216	0(+)	Group review (doc 1533
$e^+e^- \to \phi\Lambda\bar{\Lambda}$	2262	72	2(+) or 2(-) or 1(+)	Published (BAM422)
$e^+e^- \to \eta\Lambda\bar{\Lambda}$	2355	304	S-wave	Published (BAM 495)

- The paremeters of the resonances extracted from different processes are not consistent with each other, so more studies on the structures on the $\Lambda\bar{\Lambda}$ mass spectrum are needed.
- In this work, we will perform the PWA on the process of $e^+e^- \to \pi^0\Lambda\bar{\Lambda}$ at 3.773 GeV to search for the possible resonaces and determine the parameters of them.

Datasets

- BOSS version: 7.1.2 and 7.0.3
- Data sets: full data sets at 3.773 GeV, with total Lum. of 20.275 fb^{-1}, whose run numbers are 11414-13988, 14395-14604, 20448-23454, 70522-81094; data sets at 4.178 GeV, with the Lum. of 3.189 fb^{-1}, run number 43716-47066, are also run for check.
- Inclusive MC: 10 times qqbar MC samples generated by BESIII offical sources are used to estimate the background rate and investigate the possible background channels.
- Signal MC: $e^+e^- \to \pi^0\Lambda\bar{\Lambda}$ samples with events of 2M are generated with ConExc generator with PHSP model, at 3.773 and 4.178 GeV. The input linehape is determined using R-scan data.

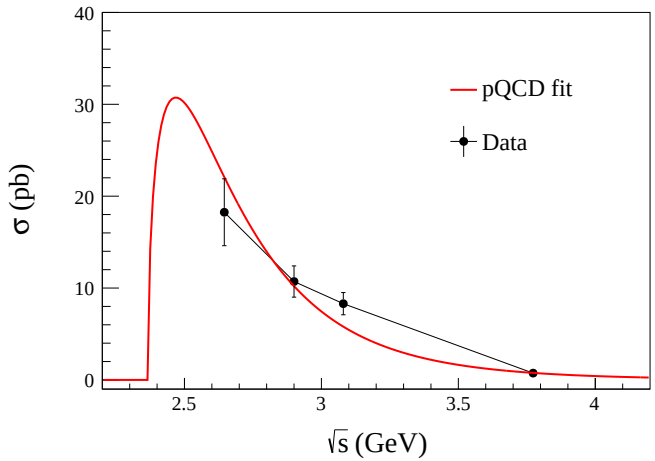


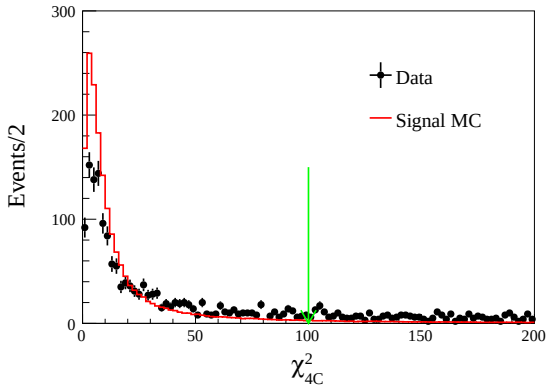
Figure: Fit result of lineshape for the process $e^+e^- \to \pi^0\Lambda\bar{\Lambda}$ by pQCD.

Event selection for $e^+e^- \to \pi^0\Lambda\bar{\Lambda}$

- Good charged track: $V_r < 10$ cm and $|V_z| < 30$ cm; $|\cos\theta| < 0.93$; nGood$\geq$4;
- Good photon: $|\cos\theta_\gamma| < 0.8$ for barrel and $0.86 < |\cos\theta_\gamma| < 0.92$ for endcaps; $E_\gamma \geq 0.025$ GeV barrel and 0.050 GeV endcaps; $0 \leq T \leq 700$ ns; $\theta(\gamma, \pi^\pm\&p) \geq 10^\circ$ ($\theta(\gamma, \bar{p}) \geq 20^\circ$); nGam$\geq$2;
- PID: information of dE/dx and TOF used, Prob(p) > Prob(π&K) for p($\bar{p}$). Prob(π) > Prob(K&p) for π; $n_p \geq 1$, $n_{\bar{p}} \geq 1$, $n_{\pi^-} \geq 1$, $n_{\pi^+} \geq 1$;
- Vertex fit: Fit to all $p\pi^-$ and $\bar{p}\pi^+$ pairs, the combination with minimum $\chi^2_{\rm Total} = \chi^2_{\rm Pri} + \chi^2_{\rm Sec}$ chosen as Λ and $\bar{\Lambda}$ candidates, respectively;
- A successful 4C-kinematic fit on hypothesis of $\gamma\gamma\Lambda\bar{\Lambda}$ should be performed by looping all γ pairs, and the combination with minimum chi-square ($\chi^2_{\rm 4C}$) is selected.
- To improve the resolution of π^0, we apply 5C (four momentum and mass of π^0) to the events passing the 4C fit, but with a very loose $\chi^2_{\rm 5C}$ requirement, making no signal events will be killed by the 5C fit.

Event selection for $e^+e^- \to \pi^0\Lambda\bar{\Lambda}$: further selection

After above selections, some additional requirements are appllied: (1) $\chi^2_{4C} \leq 100$. (2) $1.111 \leq M_{\Lambda(\bar{\Lambda})} \leq 1.121$ GeV/c^2. (3) $0.120 \leq M_{\gamma\gamma} \leq 0.148$ GeV/c^2 ($0.064 \leq M_{\gamma\gamma} \leq 0.092$ GeV/c^2 and $0.176 \leq M_{\gamma\gamma} \leq 0.204$ GeV/c^2 for sidebands).



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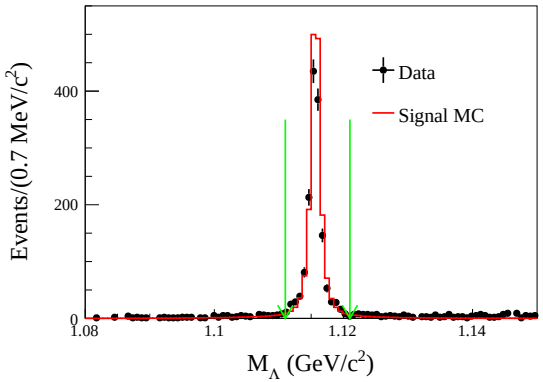

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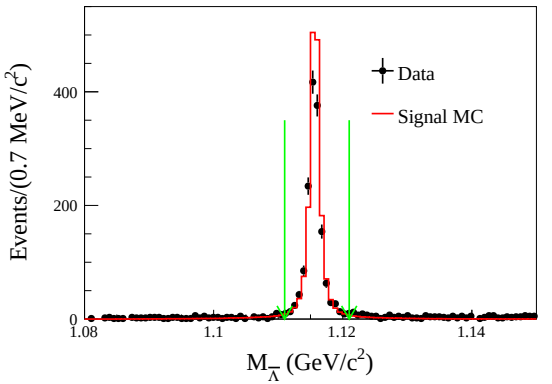

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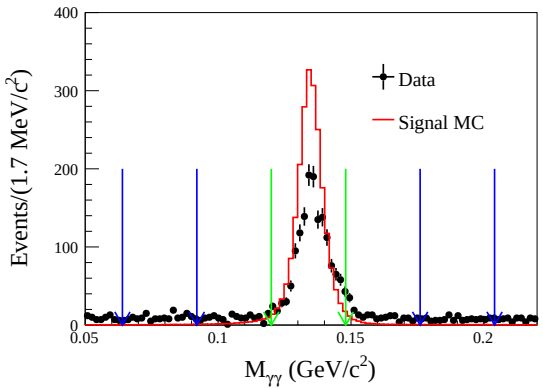


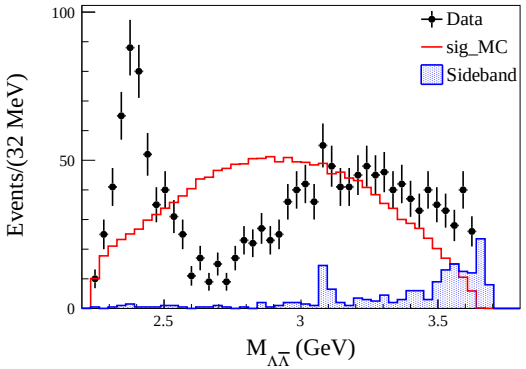
(d)

Topo. analysis of inclusive MC

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$string \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}$	0	189628	189628
2	$string \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to \pi^- p$	$\pi^0\pi^+\pi^- p\bar{p}\gamma$	3	8303	197931
3	$string \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}\gamma$	2	8265	206196
4	$string \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}$	1	947	207143
5	$string \to \pi^0\Delta^{++}\bar{\Delta}^{++}, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{++} \to \pi^-\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}$	6	408	207551
6	$string \to \pi^0\Sigma^0\bar{\Sigma}^0, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}\gamma\gamma$	4	260	207811
7	$string \to \bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to \pi^- p$	$\pi^+\pi^- p\bar{p}\gamma$	7	177	207988
8	$string \to \Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	9	174	208162
9	$string \to \pi^-\bar{\Lambda}\Sigma^+, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^+ \to \pi^0 p$	$\pi^0\pi^+\pi^- p\bar{p}$	13	43	208205
10	$string \to \pi^0\pi^-\bar{p}\Delta^{++}, \Delta^{++} \to \pi^+ p$	$\pi^0\pi^+\pi^- p\bar{p}$	16	39	208244
11	$string \to \pi^+\Lambda\bar{\Sigma}^-, \Lambda \to \pi^- p, \bar{\Sigma}^- \to \pi^0\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}$	22	39	208283
12	$string \to \Sigma^0\bar{\Sigma}^0, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma\gamma$	5	35	208318
13	$string \to \pi^0\pi^+ p\bar{\Delta}^{++}, \bar{\Delta}^{++} \to \pi^-\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}$	8	28	208346
14	$string \to p\bar{p}a_1^0, a_1^0 \to \pi^-\rho^+, \rho^+ \to \pi^0\pi^+$	$\pi^0\pi^+\pi^- p\bar{p}$	17	25	208371
15	$string \to p\bar{p}h_1(1170), h_1(1170) \to \pi^+\rho^-, \rho^- \to \pi^0\pi^-$	$\pi^0\pi^+\pi^- p\bar{p}$	18	24	208395
16	$string \to p\bar{p}a_1^0, a_1^0 \to \pi^+\rho^-, \rho^- \to \pi^0\pi^-$	$\pi^0\pi^+\pi^- p\bar{p}$	26	20	208415
17	$string \to p\bar{p}h_1(1170), h_1(1170) \to \pi^-\rho^+, \rho^+ \to \pi^0\pi^+$	$\pi^0\pi^+\pi^- p\bar{p}$	21	19	208434
18	$string \to K^+\bar{p}\Lambda, \Lambda \to \pi^- p$	$\pi^- K^+ p\bar{p}$	20	14	208448
19	$string \to \pi^0\bar{\Lambda}\Sigma^{*0}, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^{*0} \to \pi^0\Lambda, \Lambda \to \pi^- p$	$\pi^0\pi^0\pi^+\pi^- p\bar{p}$	11	14	208462
20	$string \to \pi^0\Lambda\bar{\Lambda}, \pi^0 \to e^+e^-\gamma^F, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$e^+e^-\pi^+\pi^- p\bar{p}\gamma^F$	27	11	208473
21	$string \to \pi^0\Lambda\bar{\Sigma}^{*0}, \Lambda \to \pi^- p, \bar{\Sigma}^{*0} \to \pi^0\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^0\pi^+\pi^- p\bar{p}$	29	11	208484
22	$string \to K^- p\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+ K^- p\bar{p}$	23	10	208494
23	$string \to \pi^0\pi^+\pi^- p\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}$	28	8	208502
24	$string \to a_2^0 p\bar{p}, a_2^0 \to \pi^-\rho^+, \rho^+ \to \pi^0\pi^+$	$\pi^0\pi^+\pi^- p\bar{p}$	12	6	208508
25	$string \to \pi^0\pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^0\pi^+\pi^- p\bar{p}$	30	6	208514
26	$string \to \pi^-\bar{\Sigma}^0\Sigma^+, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Sigma^+ \to \pi^0 p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}\gamma$	19	5	208519
27	$string \to \bar{\Lambda}\Sigma^{*0}, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^{*0} \to \pi^0\Lambda, \Lambda \to \pi^- p$	$\pi^0\pi^+\pi^- p\bar{p}$	10	5	208524
28	$string \to \pi^0\pi^-\bar{\Delta}^0 p, \bar{\Delta}^0 \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}$	25	4	208528
29	$string \to \pi^+\Sigma^0\bar{\Sigma}^-, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^- \to \pi^0\bar{p}, \Lambda \to \pi^- p$	$\pi^0\pi^+\pi^- p\bar{p}\gamma$	24	4	208532
30	$string \to p\bar{p}a_1^0, a_1^0 \to \pi^+\rho^-\gamma^F, \rho^- \to \pi^0\pi^-$	$\pi^0\pi^+\pi^- p\bar{p}\gamma^F$	15	3	208535
31	$string \to p\bar{p}h_1(1170), h_1(1170) \to \pi^0\rho^0, \rho^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^- p\bar{p}$	32	3	208538
32	$string \to \pi^-\bar{\Delta}^+\Delta^{++}, \bar{\Delta}^+ \to \pi^0\bar{p}, \Delta^{++} \to \pi^+ p$	$\pi^0\pi^+\pi^- p\bar{p}$	38	3	208541
33	$string \to \pi^0\Lambda\bar{\Sigma}^0, \pi^0 \to e^+e^-\gamma^F, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$e^+e^-\pi^+\pi^- p\bar{p}\gamma^F\gamma$	37	2	208543

- About 10% backgound remaining.

Distributions of some varibles after 4C fit at 3.773 GeV



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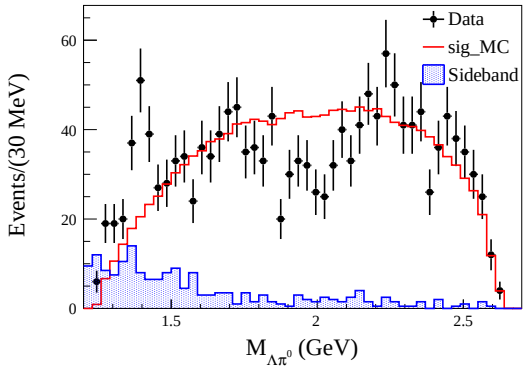

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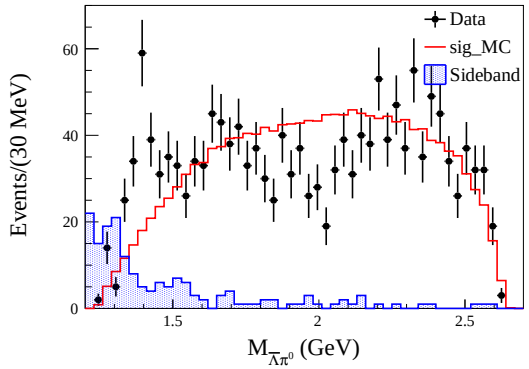

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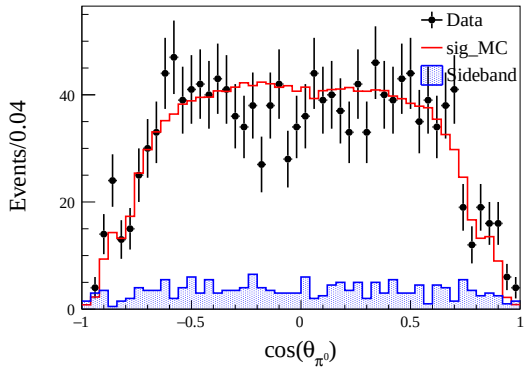

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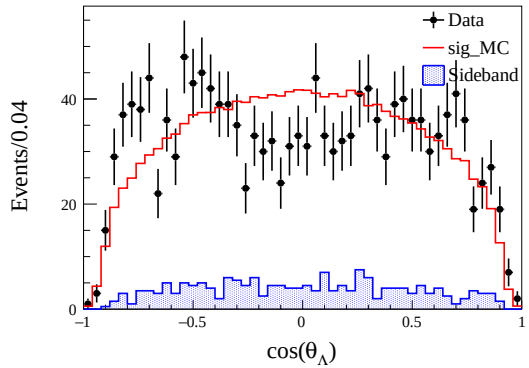

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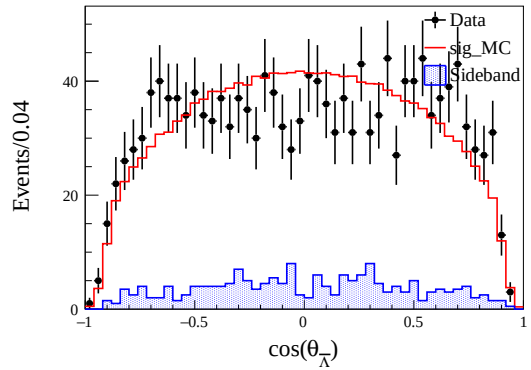
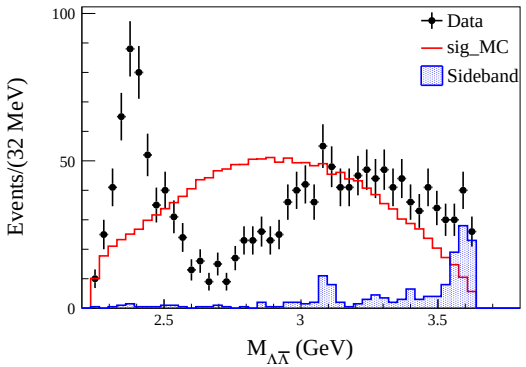


(f)

Distributions of some varibles including 5C fit at 3.773 GeV



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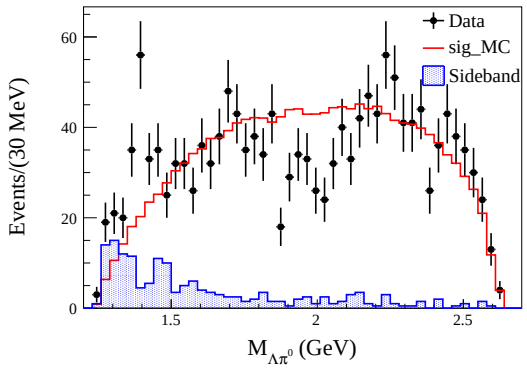

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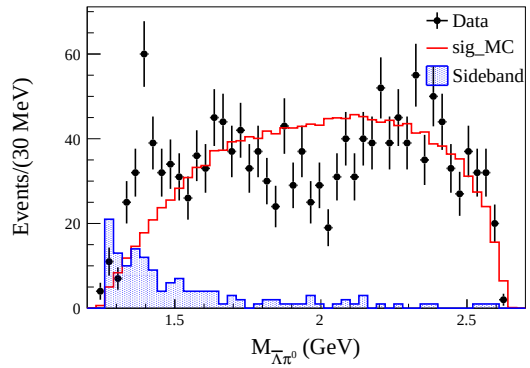

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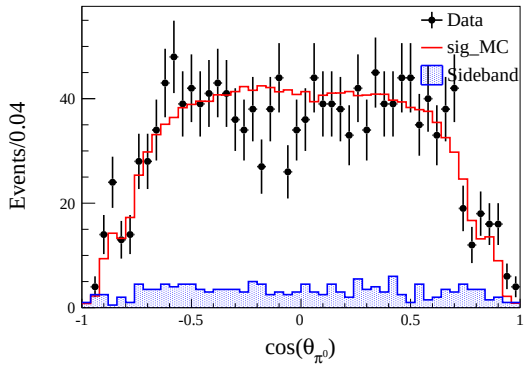

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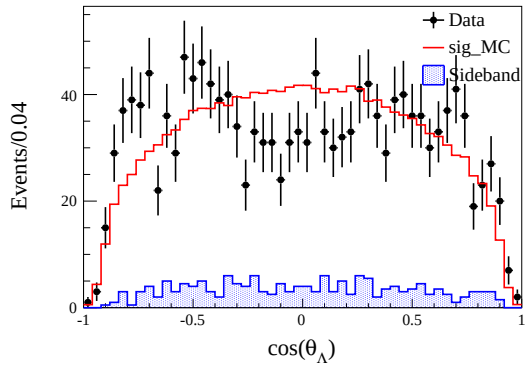

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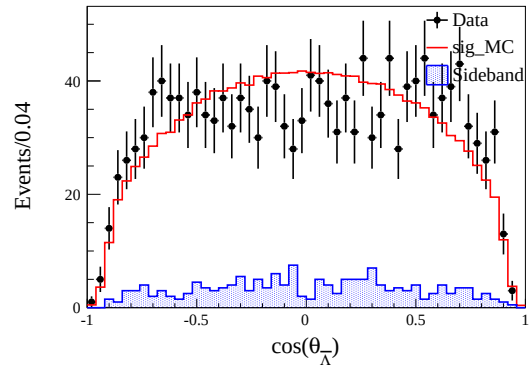
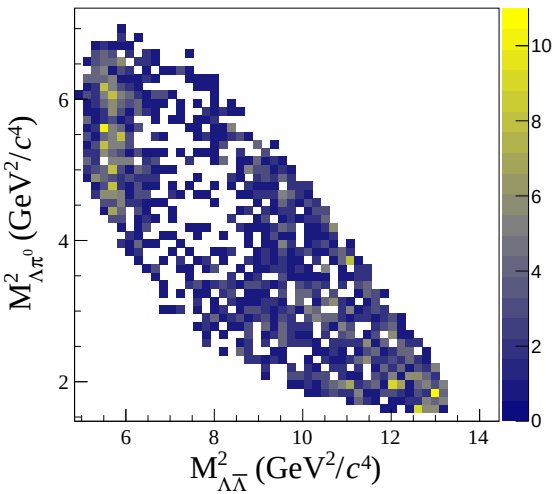


(l)

Daliz plot at 3.773 GeV



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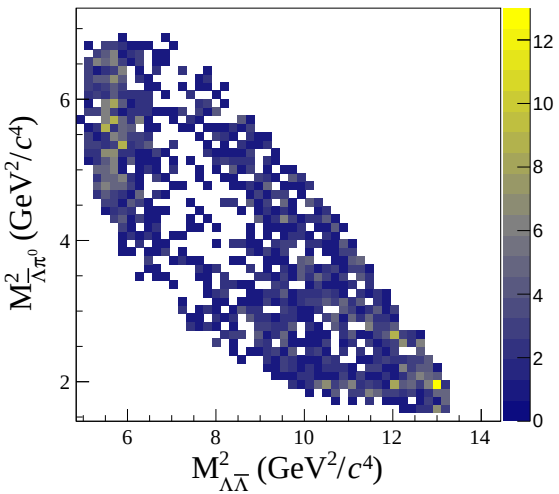

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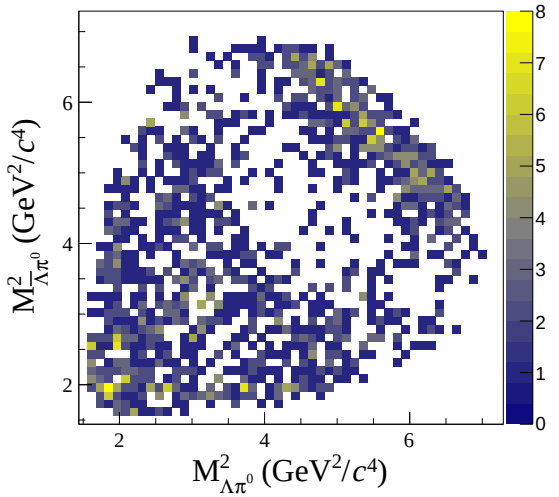
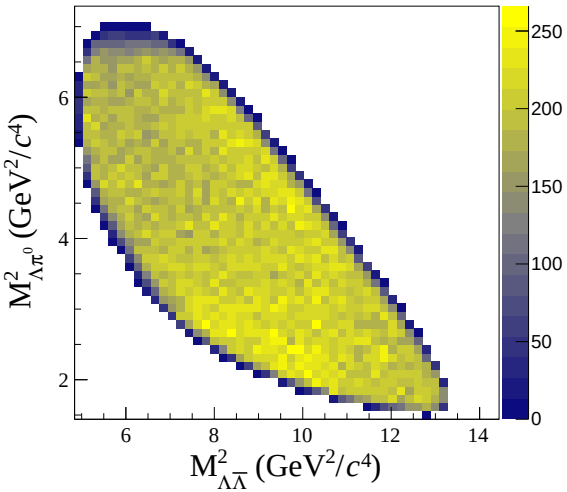
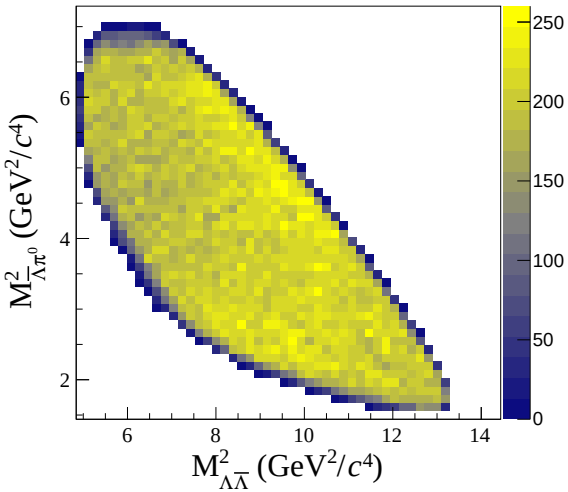
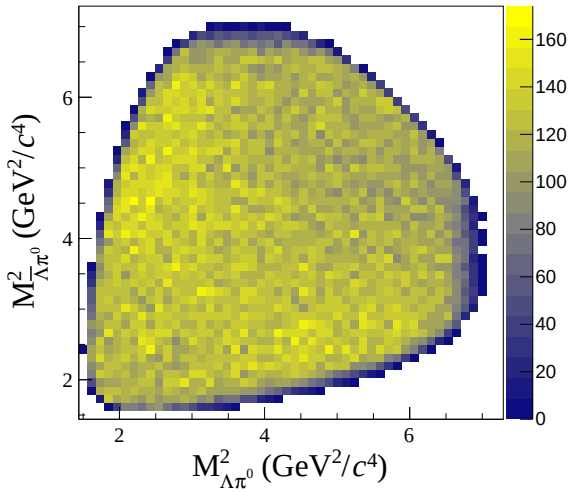


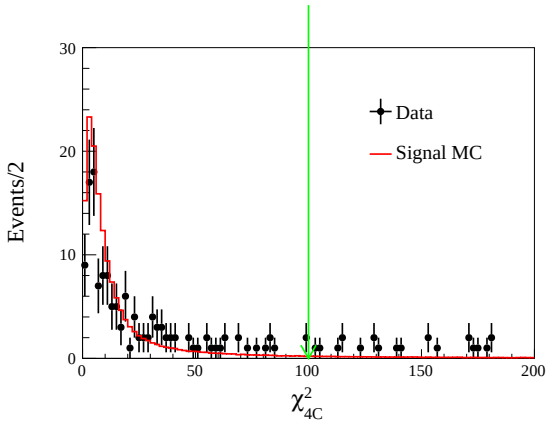
(o)







Event selection for $e^+e^- \to \pi^0\Lambda\bar{\Lambda}$: further selection (4180)



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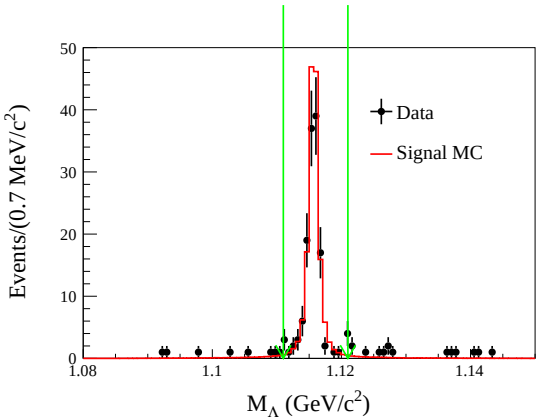

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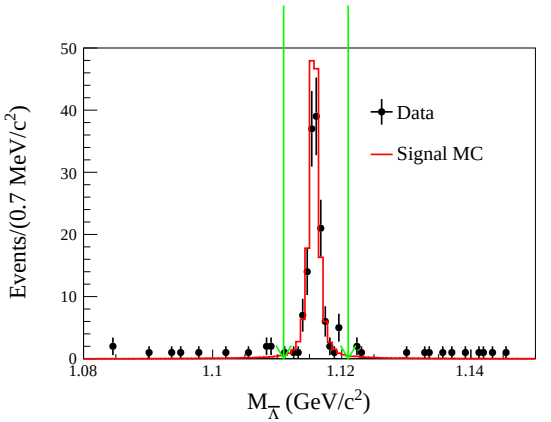
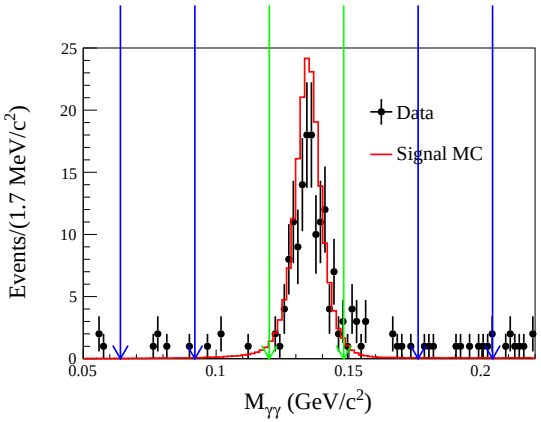


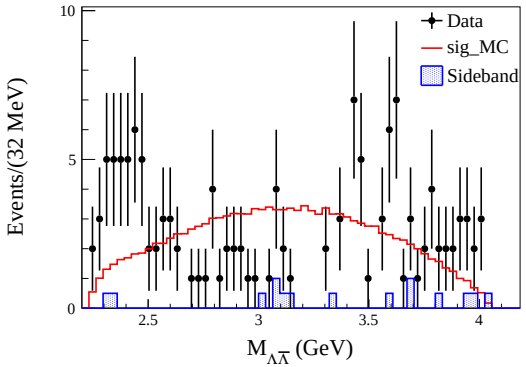
(u)



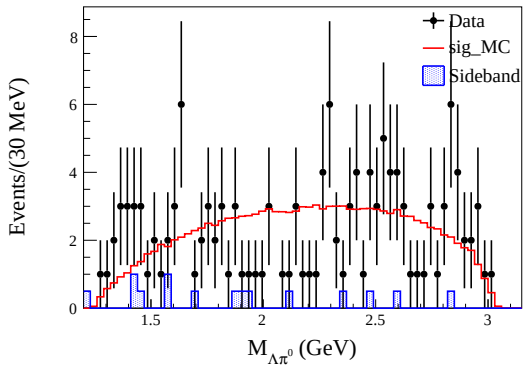
(v)

Figure: Distributions of χ^2_{4C} (a), M_Λ (b), $M_{\bar{\Lambda}}$ (c), and $M_{\gamma\gamma}$ after requirements of χ^2_{4C} and $M_{\Lambda(\bar{\Lambda})}$ (d) for process $\pi^0\Lambda\bar{\Lambda}$. The red arrow refers to the requirement and the blue arrow refers to the sideband.

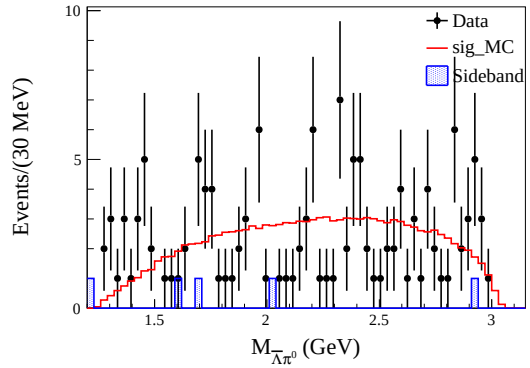
Distributions of some varibles (4180)



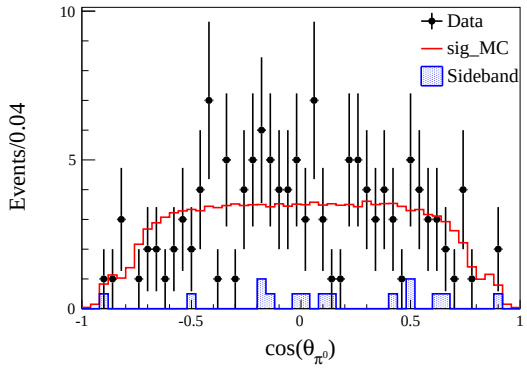
(a)



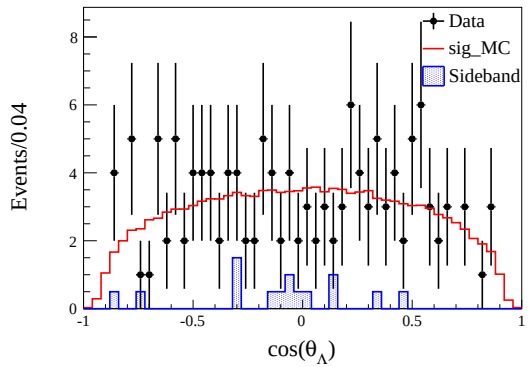
(b)



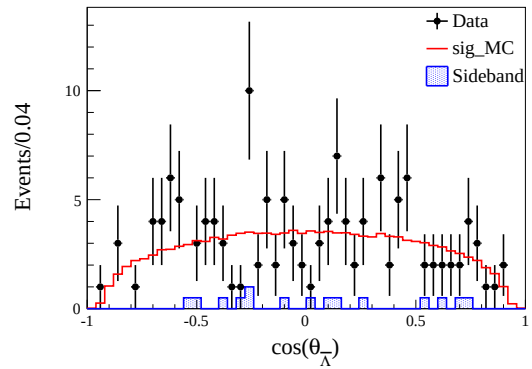
(c)



(d)



(e)



(f)

Summary and next to do

- Event selection criteria have applied to data sets at $\sqrt{s} = 3.773$ and 4.178 GeV, and $\pi^0\Lambda\bar{\Lambda}$ samples are selected.
- According to the topo. analysis of inclusive MC, the backgound level is about 10%.
- By investigating the two body invariant mass spectrum and the Daliz plot, possible structure is observed at around 2.4 GeV on $M_{\Lambda\bar{\Lambda}}$ spectrum, and contribution of $\Sigma(1835)$ is observed on the $M_{\pi^0\Lambda(\bar{\Lambda})}$ spectrum.

- Optimizing of the selection criteria and more detailed background analysis is needed.
- Possible structures on $M_{\Lambda\bar{\Lambda}}$ and $M_{\pi^0\Lambda(\bar{\Lambda})}$ spectra will be investigated with the PWA under the TF-PWA frame

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Thanks for your attention!