PWA of $\psi(3686) \to pK^{-}\bar{\Lambda}\eta + c.c.$

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Outline

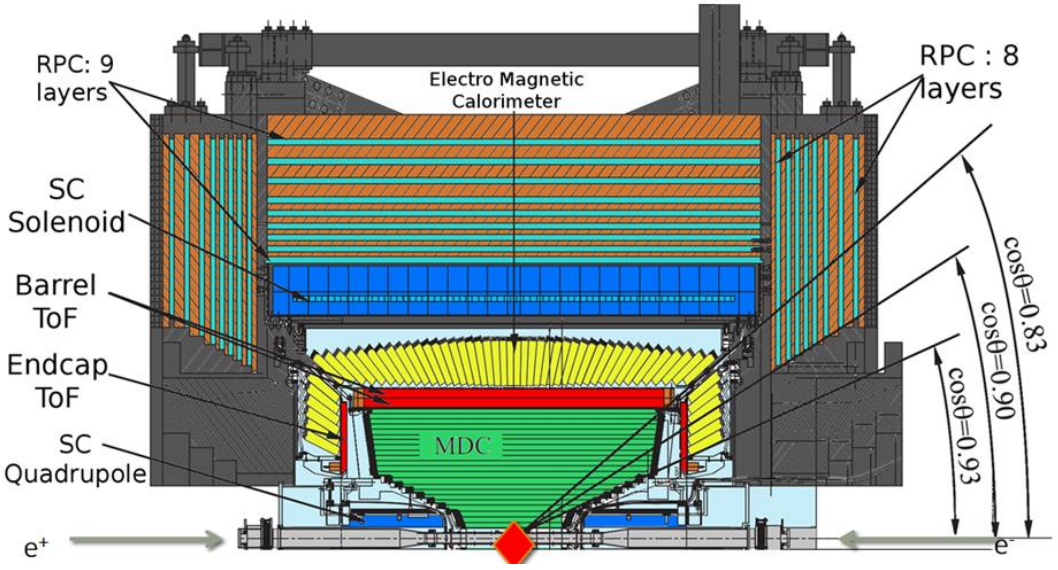
1. Motivation
2. BEPCII and BESIII
3. Data samples
4. Event selection criteria
5. Background study
6. Partial wave analysis
7. Systematic uncertainties
8. Summary

Motivation

- The study of charmonium decay plays a crucial role in our understanding of the low-energy regime of QCD. Among the charmonium decays, the processes of $\psi(3686)$ and J/ψ decaying into baryon pairs have been understood in terms of $c\bar{c}$ annihilations into three gluons or into a virtual photon.
- Currently, there is a significant amount of experimental and theoretical research on the decay of $\psi(3686)$ into a pair of octet-baryons. However, there is a lack of research on decay modes with excited state as the final state. The $\psi(3686)$ has relatively large mass, which allows for the search of heavier excited-state hyperons.
- In this analysis, the four-body decay of $\psi(3686) \to pK^{-}\bar{\Lambda}\eta + c.c.$ is investigated with a partial wave analysis (PWA) to measure its branching fraction and search for possible potential intermediate excited states.

BEPCII and BESIII

- **Be**ijing **S**pectrometer III (BESIII), a large general-purpose detector working in the τ-charm energy region operating at **B**eijing **E**lectron-**P**ositron **C**ollider II (BEPCII).
- Main studys
  - ✓ Light mesons and light baryons
  - ✓ Charmonium, including exotic mesons and baryons containing charmonium
  - ✓ QCD and τ physics
  - ✓ Searches for new physics



Data samples

$\psi(3686)$ data samples

Year	$\sqrt{s}\,(GeV)$	Size ($\times 10^6$)	
		Data	Inclusive MC
2009	3.686	107.7	106
2012	3.686	345.4	341
2021	3.686	2259.3	2300

Continuum background data samples

$\sqrt{s}\,(GeV)$	Luminosity $\left(pb^{-1}\right)$
3.650	454
3.682	404
3.773	20274.8

Signal MC samples

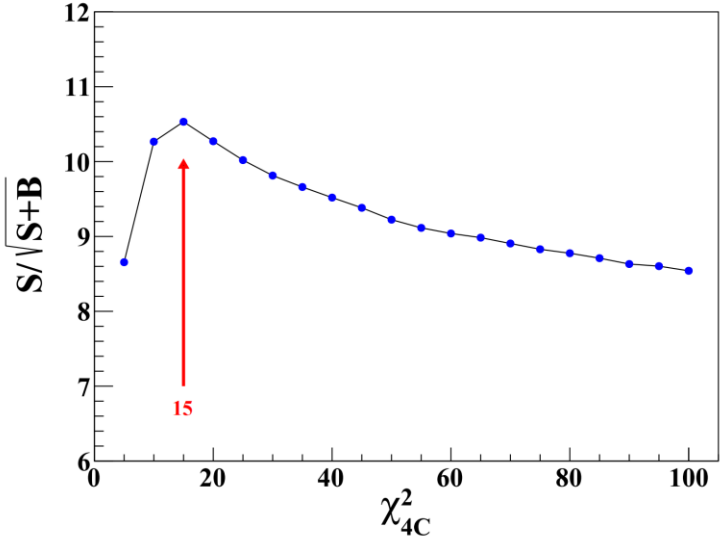
Channel	Generic Mode	Size ($\times 10^6$)
$\psi(3686) \to pK^-\bar{\Lambda}\eta, \bar{\Lambda} \to \bar{p}\pi^+, \eta \to \gamma\gamma$	PHSP	1.4
$\psi(3686) \to \bar{p}K^+\Lambda\eta, \Lambda \to p\pi^-, \eta \to \gamma\gamma$	PHSP	1.4

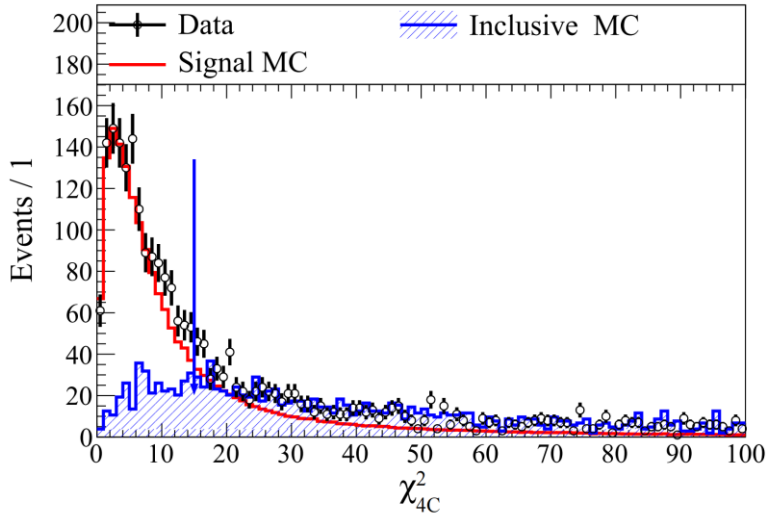
BOSS version: 7.0.3, 7.0.9, 7.1.2

Event selection criteria

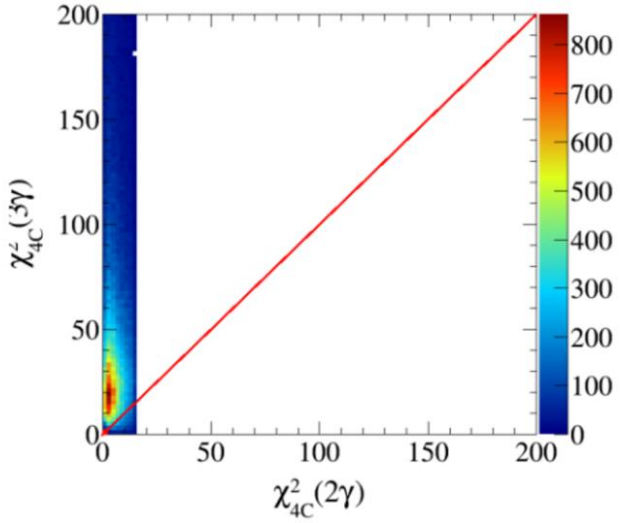
1. **Charged tracks:**
   - $|V_{xy}| < 1\ cm,\ |V_z| < 10\ cm$ (not from $\bar{\Lambda}/\Lambda$ decay)
   - No vertex constraint (from $\bar{\Lambda}/\Lambda$ decay)
   - $|cos\theta| < 0.93$
   - $N_{tot} \geq 4$
2. **PID:**
   - $N_p \geq 1,\ N_K \geq 1$
   - The tracks are assigned to the particle type with the highest confidence level
3. **Good photons:**
   - $0 \leq TDC \leq 14$
   - Barrel: $E > 25\ MeV,\ |cos\theta| < 0.8$
   - End cap: $E > 50\ MeV,\ 0.86 < |cos\theta| < 0.92$
   - $N_\gamma \geq 2$
4. **$\bar{\Lambda}/\Lambda$ reconstruction:**
   - Combining pairs of oppositely charged tracks with pion and proton mass hypotheses satisfying a secondary vertex constraint
5. **Vertex fit:**
   - The $pK^-/\bar{p}K^+$ pair is fitted to a common vertex
6. **Kinematic fit:**
   - 4-momentum conservation constrsint (4C) kinematic fit under hypothesis of $\psi(3686) \to pK^-\bar{\Lambda}\eta/\bar{p}K^+\Lambda\eta$

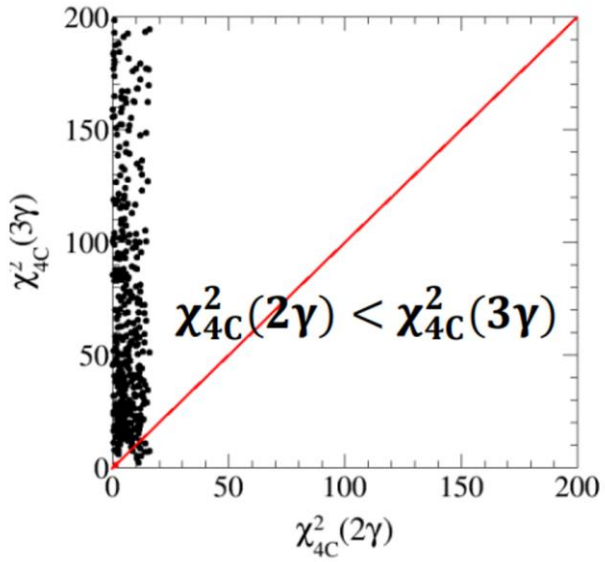
Event selection criteria





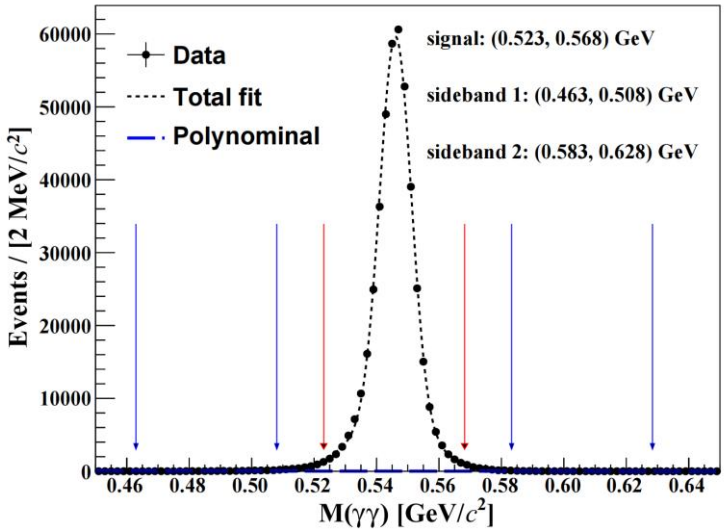
$$\chi^2_{4C}(2\gamma pK^-\bar{\Lambda}) < 15$$

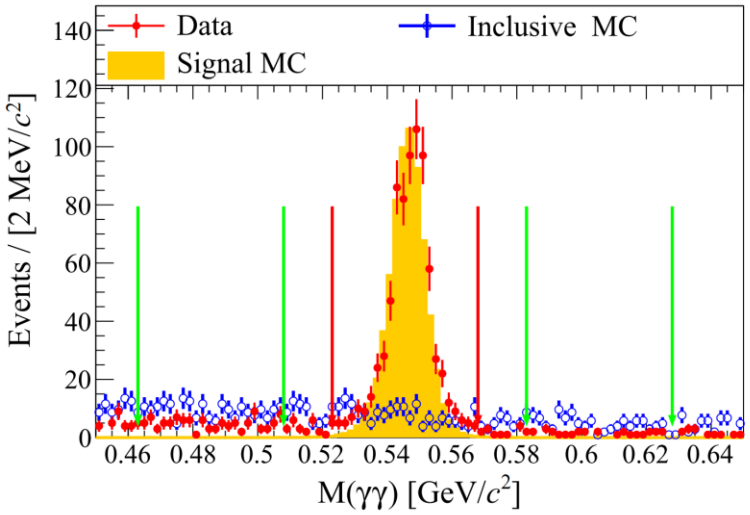




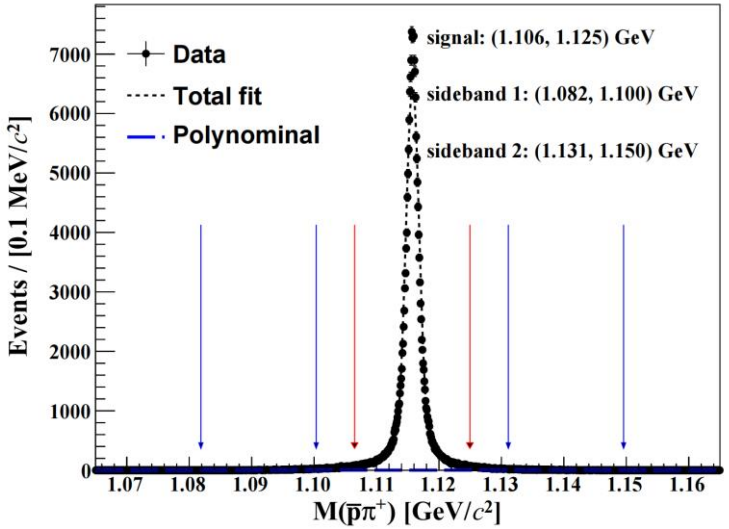
$$\chi^2_{4C}(2\gamma pK^-\bar{\Lambda}) < \chi^2_{4C}(3\gamma pK^-\bar{\Lambda})$$

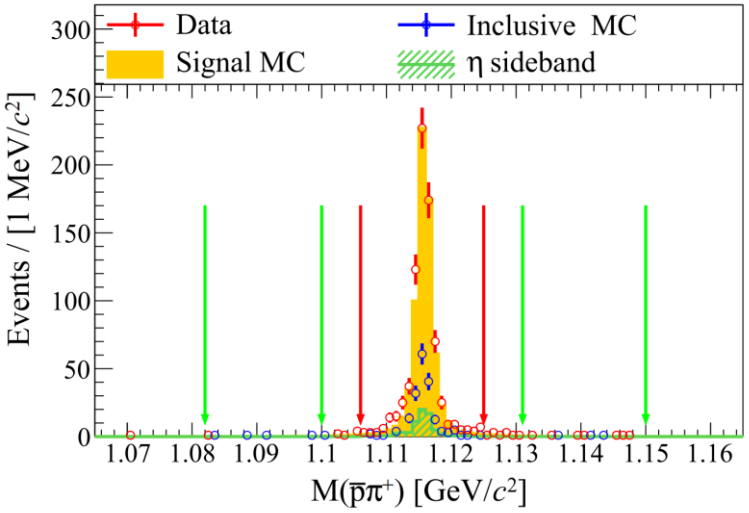
Event selection criteria





η mass window:
$(0.523 - 0.568) GeV$





$\bar{\Lambda}$ mass window:
$(1.106 - 1.125) GeV$

Background study

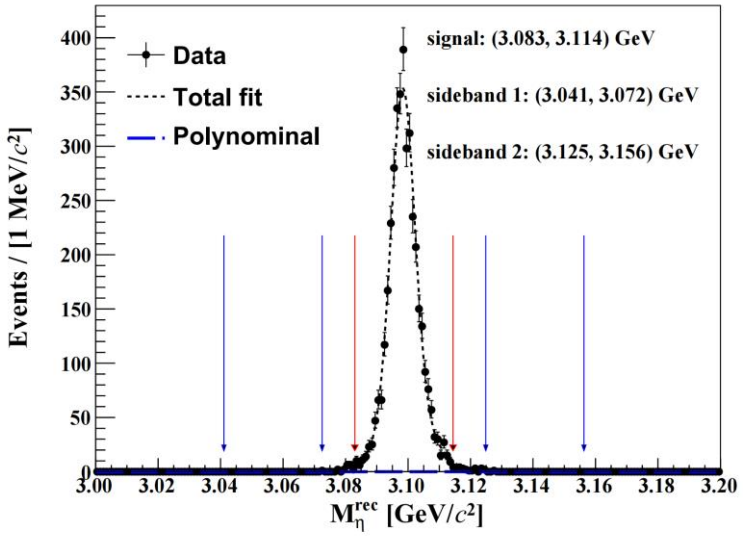
rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$\psi' \to \eta J/\psi, \eta \to \gamma\gamma, J/\psi \to K^- p\bar{\Lambda}, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma\gamma$	0	290607	290607
2	$\psi' \to \chi_{c0}\gamma, \chi_{c0} \to K^{*-} p\bar{\Lambda}, K^{*-} \to \pi^0 K^-, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^0\pi^+ K^- p\bar{p}\gamma$	1	101	290708
3	$\psi' \to \chi_{c1}\gamma, \chi_{c1} \to J/\psi\gamma, J/\psi \to K^- p\bar{\Lambda}, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma\gamma$	4	65	290773
4	$\psi' \to \chi_{c1}\gamma, \chi_{c1} \to K^{*-} p\bar{\Lambda}, K^{*-} \to \pi^0 K^-, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^0\pi^+ K^- p\bar{p}\gamma$	2	38	290811
5	$\psi' \to \chi_{c2}\gamma, \chi_{c2} \to K^{*-} p\bar{\Lambda}, K^{*-} \to \pi^0 K^-, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^0\pi^+ K^- p\bar{p}\gamma$	12	18	290829
6	$\psi' \to \chi_{c0}\gamma, \chi_{c0} \to J/\psi\gamma, J/\psi \to K^- p\bar{\Lambda}, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma\gamma$	6	17	290846
7	$\psi' \to \eta K^- p\bar{\Lambda}, \eta \to \gamma\gamma, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma\gamma$	3	9	290855
8	$\psi' \to \chi_{c0}\gamma, \chi_{c0} \to K^{*-} p\bar{\Lambda}, K^{*-} \to K^- \gamma, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma\gamma$	5	9	290864
9	$\psi' \to J/\psi\gamma\gamma, J/\psi \to K^- p\bar{\Lambda}, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma\gamma$	8	3	290867
10	$\psi' \to \chi_{c1}\gamma, \chi_{c1} \to K^{*-} p\bar{\Lambda}, K^{*-} \to K^- \gamma, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma\gamma$	10	3	290870
11	$\psi' \to K_2^{*-} p\bar{\Lambda}, K_2^{*-} \to \eta K^-, \bar{\Lambda} \to \pi^+ \bar{p}, \eta \to \gamma\gamma$	$\pi^+ K^- p\bar{p}\gamma\gamma$	11	3	290873
12	$\psi' \to \chi_{c2}\gamma, \chi_{c2} \to K^{*-} p\bar{\Lambda}, K^{*-} \to K^- \gamma, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma\gamma$	7	3	290876
13	$\psi' \to \chi_{c0}\gamma, \chi_{c0} \to K^- p\bar{\Lambda}(1520)^0, \bar{\Lambda}(1520)^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma\gamma$	9	2	290878
14	$\psi' \to \chi_{c0}\gamma, \chi_{c0} \to \Lambda(1520)^0 \bar{\Lambda}(1520)^0, \Lambda(1520)^0 \to K^- p, \bar{\Lambda}(1520)^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma\gamma$	14	2	290880
15	$\psi' \to \chi_{c0}\gamma, \chi_{c0} \to K^- p\bar{\Lambda}\gamma^F, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma^F\gamma$	13	1	290881
16	$\psi' \to \pi^0\pi^0 J/\psi, J/\psi \to K^- p\bar{\Lambda}, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^0\pi^0\pi^+ K^- p\bar{p}$	15	1	290882
17	$\psi' \to \chi_{c0}\gamma, \chi_{c0} \to K^{*-} p\bar{\Lambda}, K^{*-} \to \pi^- \bar{K}^0, \bar{\Lambda} \to \pi^+ \bar{p}, \bar{K}^0 \to K_L^0$	$K_L^0\pi^+\pi^- p\bar{p}\gamma$	16	1	290883
18	$\psi' \to K^{*-} p\bar{\Lambda}\gamma^F, K^{*-} \to \pi^0 K^-, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^0\pi^+ K^- p\bar{p}\gamma^F$	17	1	290884
19	$\psi' \to K^{*-} p\bar{\Lambda}\gamma^F, K^{*-} \to K^- \gamma, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma^F\gamma$	18	1	290885
20	$\psi' \to \chi_{c1}\gamma, \chi_{c1} \to K^- p\bar{\Lambda}(1520)^0, \bar{\Lambda}(1520)^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma\gamma$	19	1	290886
21	$\psi' \to \chi_{c1}\gamma, \chi_{c1} \to \pi^0 K^- p\bar{\Lambda}, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^0\pi^+ K^- p\bar{p}\gamma$	20	1	290887
22	$\psi' \to \chi_{c1}\gamma, \chi_{c1} \to J/\psi\gamma, J/\psi \to K^- p\bar{\Sigma}^0, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma\gamma\gamma$	21	1	290888
23	$\psi' \to \chi_{c0}\gamma, \chi_{c0} \to \pi^0 K^- p\bar{\Lambda}, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^0\pi^+ K^- p\bar{p}\gamma$	22	1	290889
24	$\psi' \to \chi_{c0}\gamma, \chi_{c0} \to K^- p\bar{\Lambda}\gamma^f, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma\gamma^f$	23	1	290890
25	$\psi' \to \chi_{c2}\gamma, \chi_{c2} \to K^- p\bar{\Lambda}(1520)^0, \bar{\Lambda}(1520)^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+ K^- p\bar{p}\gamma\gamma$	24	1	290891
26	$\psi' \to \eta J/\psi, \eta \to \gamma\gamma, J/\psi \to K^- p\bar{\Lambda}, \bar{\Lambda} \to \pi^+ \bar{p}\gamma^f$	$\pi^+ K^- p\bar{p}\gamma\gamma\gamma^f$	25	1	290892

The topologies of the background events are investigated by the $\psi(3686)$ inclusive MC sample.

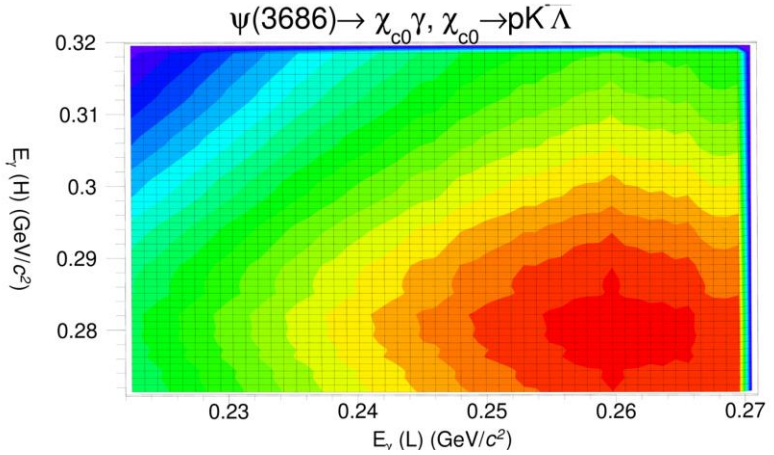
Main background:

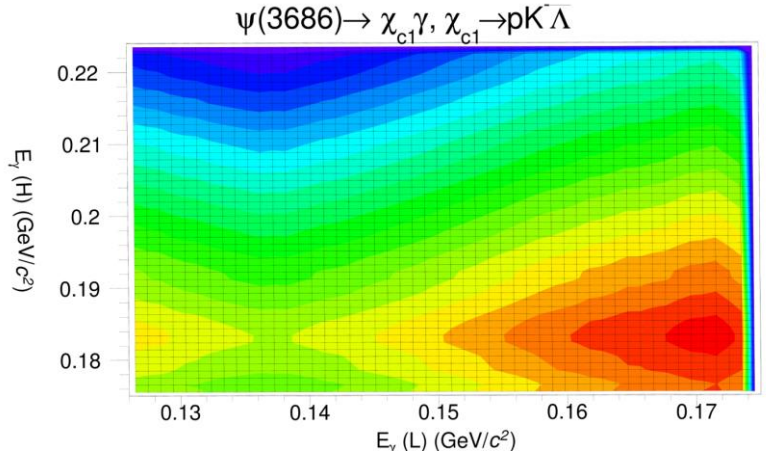
- $\psi(3686) \to \eta J/\psi$ with $J/\psi \to p K^- \overline{\Lambda}$
- $\psi(3686) \to \gamma \chi_{cJ}$ with χ_{cJ} decaying to the similar final state

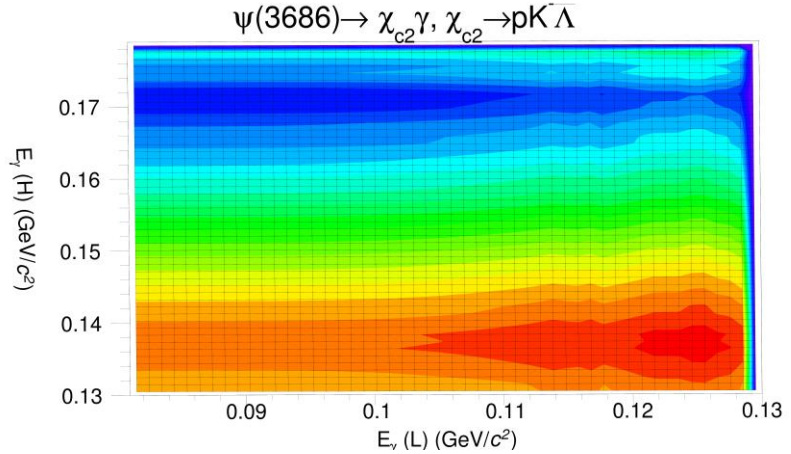
Background study



- Supress $\psi(3686) \to \eta J/\psi$ channel background by veto η recoil mass window: $(3.083 - 3.114) GeV$







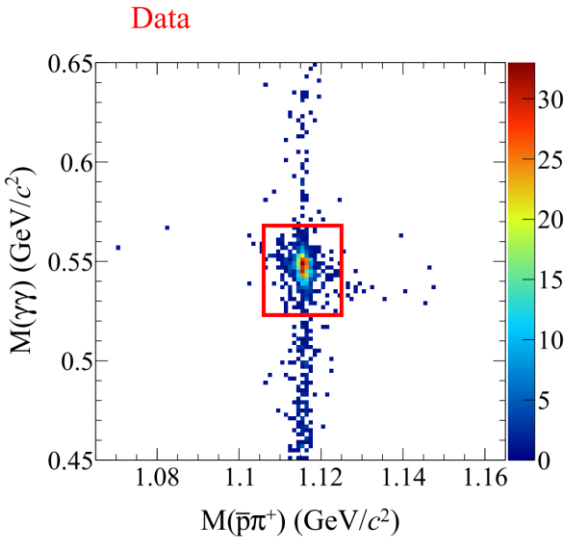
Origin	E_γ Range (GeV/c^2)
χ_{c0}	$(0.243, 0.290)$
χ_{c1}	$(0.153, 0.193)$
χ_{c2}	$(0.114, 0.140)$

- Photons wrong combinations background:

Suppress background such as $\psi(3686) \to \gamma\chi_{cJ(J=0,1,2)}$, $\chi_{cJ} \to K^{*-}p\bar{\Lambda}$ and $K^{*-} \to \pi^0 K^-$ by FOM on E_γ^{low}.

Background study

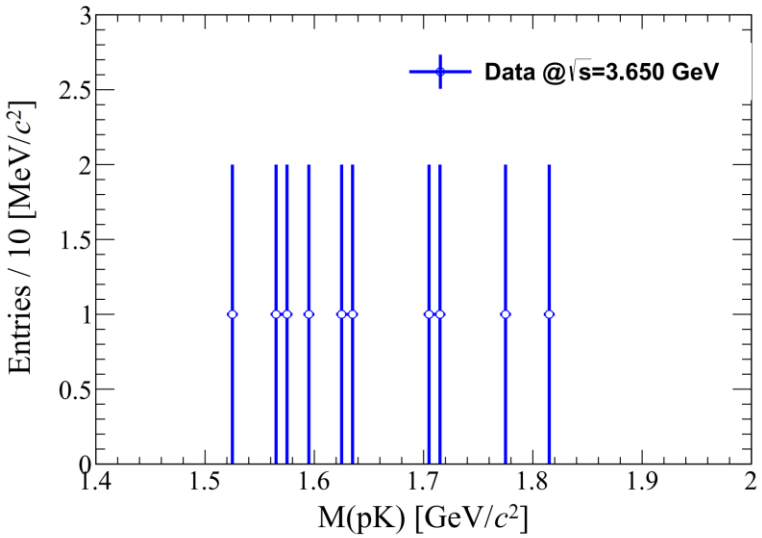
rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$\psi' \to \chi_{c0}\gamma, \chi_{c0} \to K^{*-}p\bar{\Lambda}, K^{*-} \to \pi^0 K^-, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+K^-p\bar{p}\gamma$	1	7	7
2	$\psi' \to \eta K^- p\Lambda, \eta \to \gamma\gamma, \Lambda \to \pi^+\bar{p}$	$\pi^+K^-p\bar{p}\gamma\gamma$	0	4	11
3	$\psi' \to \eta J/\psi, \eta \to \gamma\gamma, J/\psi \to K^- p\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+K^-p\bar{p}\gamma\gamma$	2	2	13
4	$\psi' \to \chi_{c0}\gamma, \chi_{c0} \to K^- p\bar{\Lambda}(1520)^0, \bar{\Lambda}(1520)^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+K^-p\bar{p}\gamma\gamma$	3	1	14
5	$\psi' \to \chi_{c1}\gamma, \chi_{c1} \to K^{*-}p\bar{\Lambda}, K^{*-} \to \pi^0 K^-, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+K^-p\bar{p}\gamma$	4	1	15
6	$\psi' \to \chi_{c0}\gamma, \chi_{c0} \to K^{*-}p\bar{\Lambda}, K^{*-} \to K^-\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+K^-p\bar{p}\gamma\gamma$	5	1	16
7	$\psi' \to \chi_{c0}\gamma, \chi_{c0} \to K^{*-}p\bar{\Lambda}, K^{*-} \to \pi^-\bar{K}^0, \bar{\Lambda} \to \pi^+\bar{p}, \bar{K}^0 \to K^0_L$	$K^0_L\pi^+\pi^-p\bar{p}\gamma$	6	1	17
8	$\psi' \to K^{*-}p\bar{\Lambda}\gamma^F, K^{*-} \to K^-\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+K^-p\bar{p}\gamma^F\gamma$	7	1	18

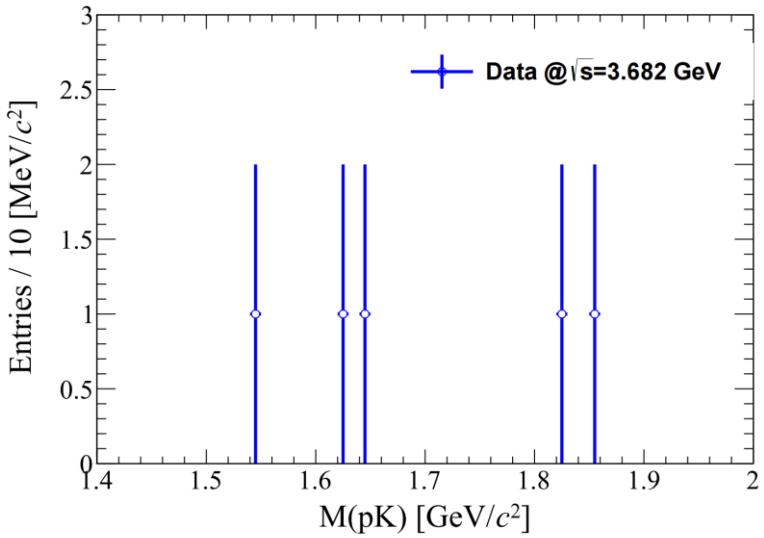


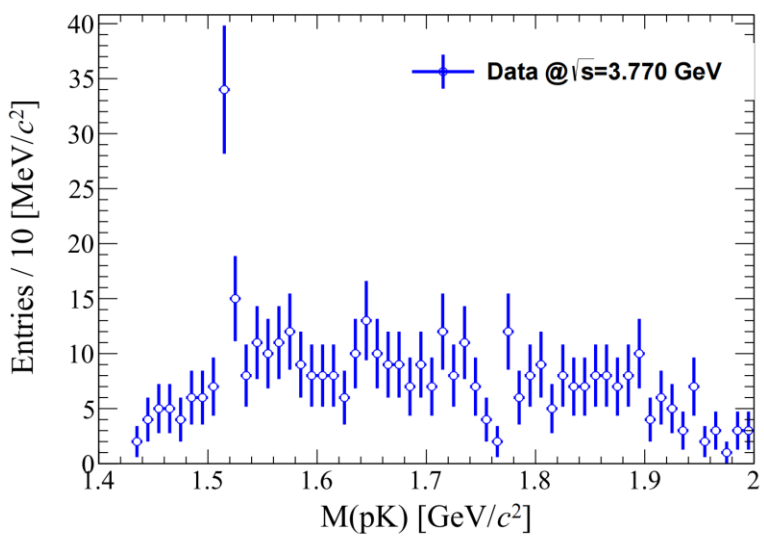
- Topologies after all selection criteria
- Only few background remains

- Obvious signal of $\bar{\Lambda}$ and η can be seen
- Peaking contribution from $\bar{\Lambda}$ sideband can be neglected

Background study





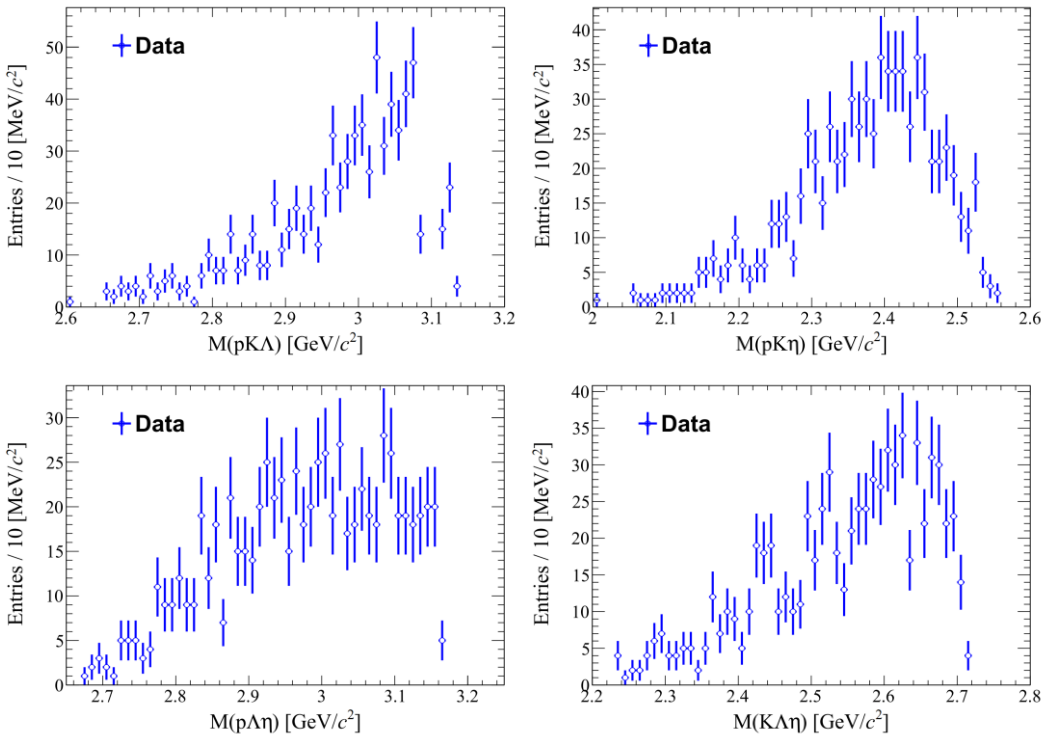


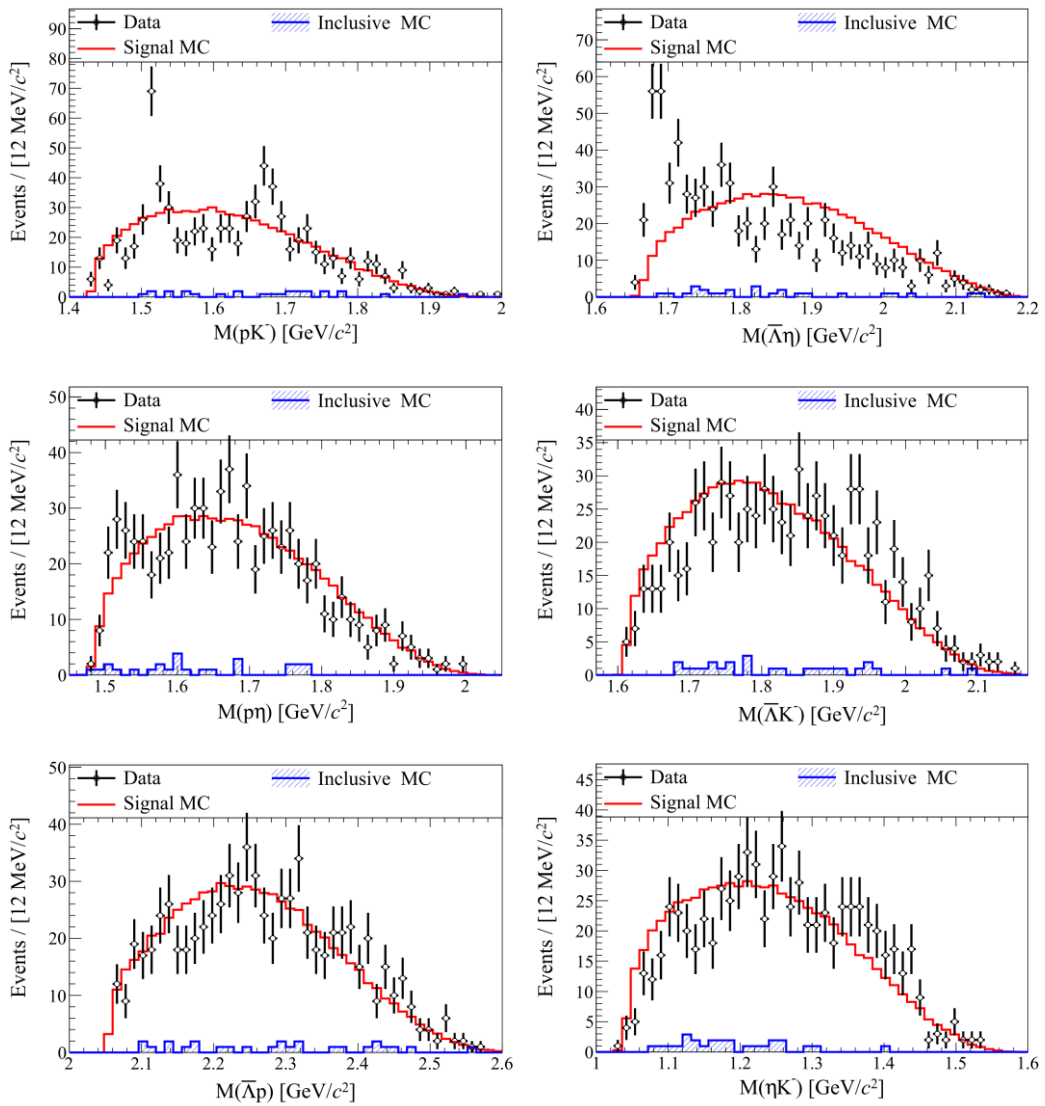
$\sqrt{s}(GeV)$	Luminosity (pb^{-1})	Scale factor	Events (after scaled)
3.686	3878.55	1.00	743
3.650	454	8.38	83.8
3.682	404	9.58	47.9
3.773	20274.8	0.20	87.8

- Continuum background:

Investigated with the data sample collected at $\sqrt{s} = 3.650, 3.682$ and $3.773 GeV$ with the same selection criteria as signal channel.

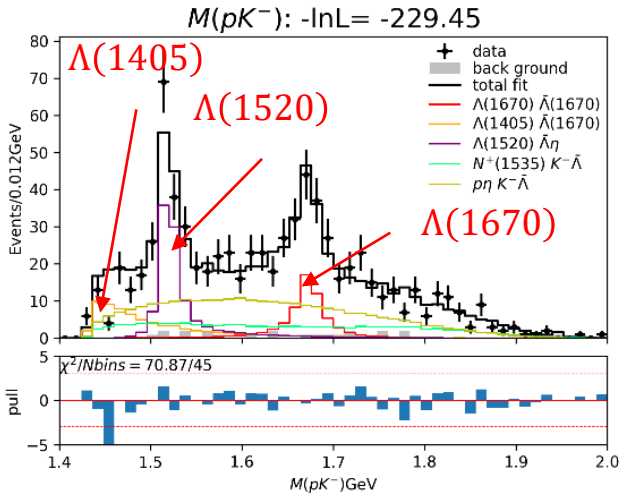
Partial wave analysis

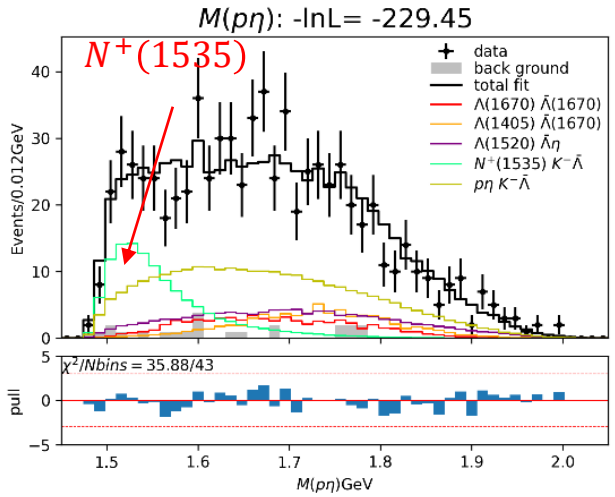


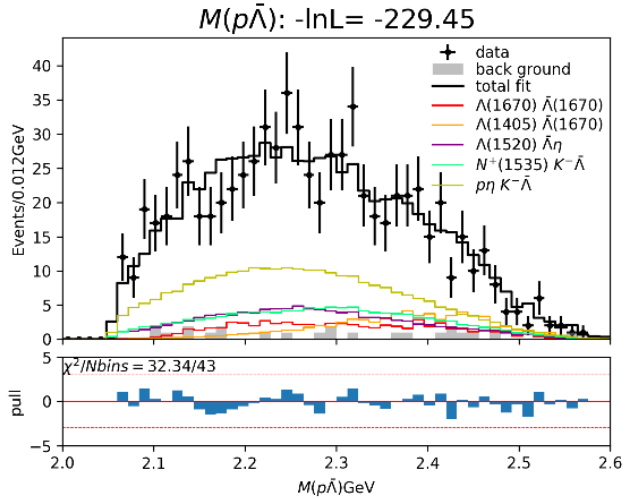


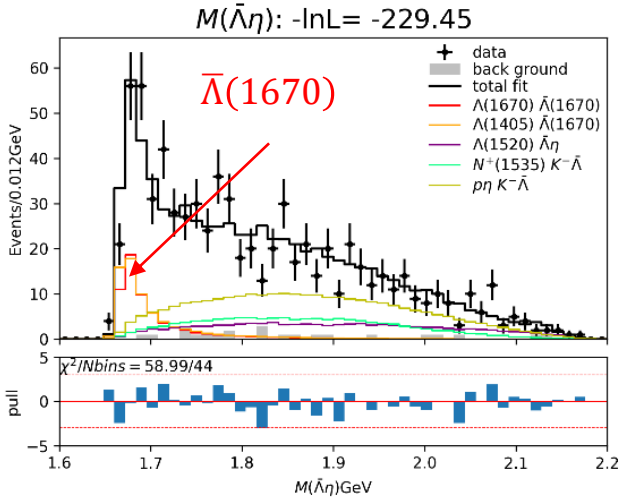
- 3-body invariant mass distribution:
  No significant structure
- 2-body invariant mass distribution:
  Significant structures are observed on M_{pK^-}, $M_{\bar{\Lambda}\eta}$ and $M_{p\eta}$.

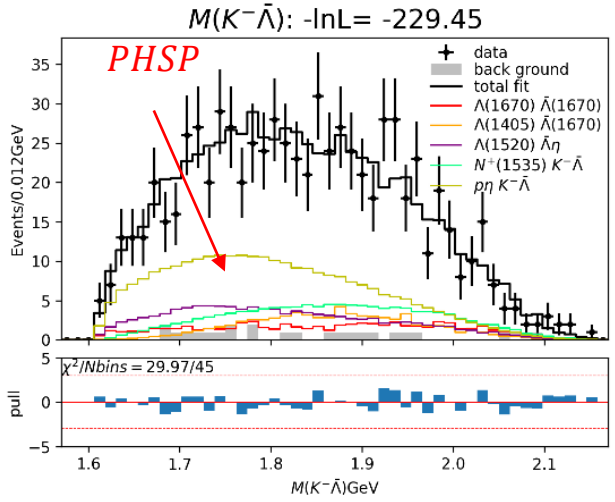
Partial wave analysis

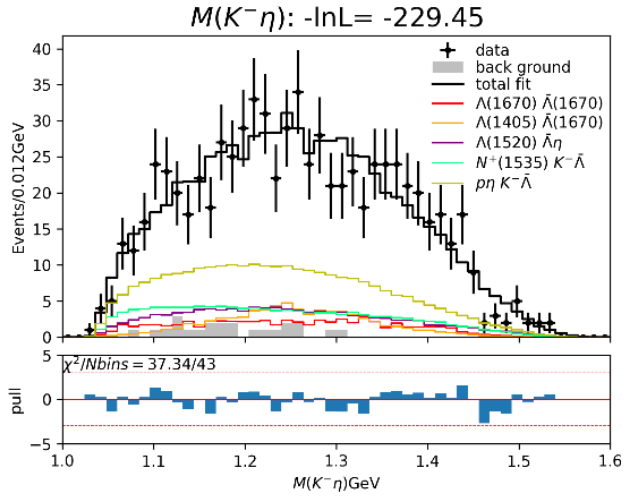












Partial wave analysis

Resonance states parameters and significance:

Resonance	Mass (MeV/c^2)	Width (MeV)	$I(J^P)$	Significance (σ)
Λ (1405)	1405.1	50.5	$0\left(\frac{1}{2}^-\right)$	10.38
Λ (1520)	1519.42	15.73	$0\left(\frac{3}{2}^-\right)$	7.80
Λ (1670)	1674	30	$0\left(\frac{1}{2}^-\right)$	9.87
$\bar{\Lambda}$ (1670)	1674	30	$0\left(\frac{1}{2}^+\right)$	17.03
N (1535)	1539	107	$\frac{1}{2}\left(\frac{1}{2}^-\right)$	8.38

Baseline solution:

- 2-body:
  $\Lambda(1405)\bar{\Lambda}(1670)$ $(pK^-$ - $\bar{\Lambda}\eta)$
  $\Lambda(1670)\bar{\Lambda}(1670)$ $(pK^-$ - $\bar{\Lambda}\eta)$
- 3-body:
  $\Lambda(1520)\bar{\Lambda}\eta$ $(pK^-$ - $\bar{\Lambda}\eta)$
  $N^+(1535)K^-\bar{\Lambda}$ $(p\eta$ - $K^-\bar{\Lambda})$
- 4-body:
  $pK^-\bar{\Lambda}\eta$(PHSP)

Decay channels fit fraction:

Fit fraction (%)	Λ (1405) $\bar{\Lambda}$ (1670)	Λ (1670) $\bar{\Lambda}$ (1670)	Λ (1520) $\bar{\Lambda}\eta$	N^+ (1535) $K^-\bar{\Lambda}$	$pK^-\bar{\Lambda}\eta$ (PHSP)
Λ (1405) $\bar{\Lambda}$ (1670)	8.4 ± 1.8	-	-	-	-
Λ (1670) $\bar{\Lambda}$ (1670)	3.5 ± 0.9	8.9 ± 1.7	-	-	-
Λ (1520) $\bar{\Lambda}\eta$	−0.0 ± 0.0	−0.0 ± 0.0	13.6 ± 2.0	-	-
N^+ (1535) $K^-\bar{\Lambda}$	−0.1 ± 0.2	0.6 ± 0.4	−0.7 ± 0.4	18.0 ± 2.9	-
$pK^-\bar{\Lambda}\eta$ (PHSP)	9.4 ± 2.8	5.7 ± 1.1	−2.3 ± 1.0	0.0 ± 0.0	34.9 ± 4.0
Total	83.8 ± 12.4				

Systematic uncetainties

The sources of systematic uncertainty for the branching fractions include tracking and photon reconstruction efficiencies, PID efficiencies, $\Lambda\left(\bar{\Lambda}\right)$ reconstruction, kinematic fit, mass windows, the branching fraction quoted, MC statistics, and the number of $\psi(3686)$ events. They are discussed as follows.

Tracking and photon efficiencies:

For proton and kaon not to originate from $\Lambda\left(\bar{\Lambda}\right)$, the uncertainty for tracking efficiency is estimated to be 1.0% for proton using the control sample $J/\psi \to p\bar{p}\pi^+\pi^-$ [27] and 1.0% for kaon according to a clean control sample of $J/\psi \to K^*K$ [28]. The uncertainty due to photon reconstruction efficiency is observed to be always less or equal to 1.0% [29].

Systematic uncetainties

PID efficiencies:

The PID efficiency uncertainties are determined to be 1.0% per proton and kaon not to originate from $\Lambda\left(\bar{\Lambda}\right)$ using the same samples [27, 28].

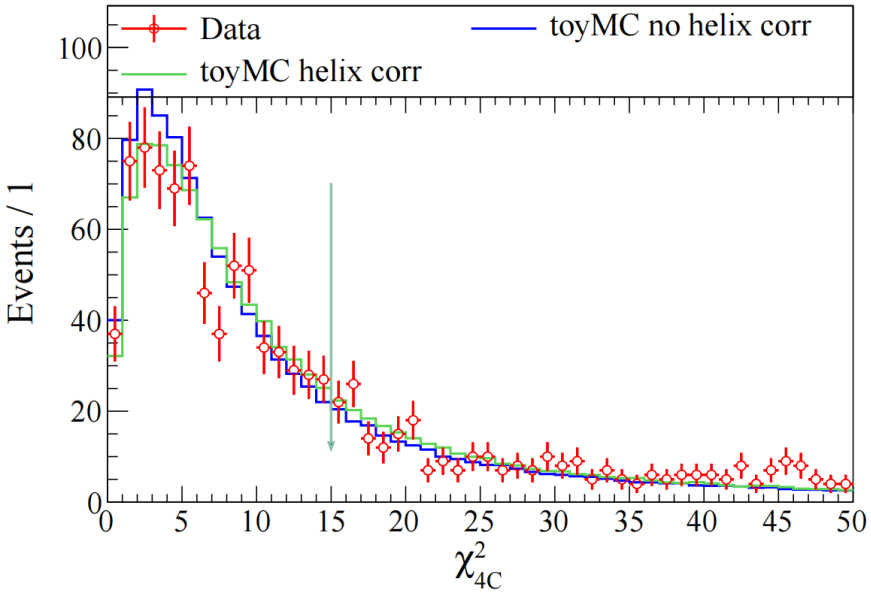
$\Lambda\left(\bar{\Lambda}\right)$ reconstruction:

The efficiencies of $\Lambda\left(\bar{\Lambda}\right)$ reconstruction, including the tracking efficiencies of the $p\pi^-$ ($\bar{p}\pi^+$) pair, decay length cut, mass window cut, vertex fit and second vertex fit, are studied by using the control samples of $J/\psi \to pK^-\bar{\Lambda} + c.c.$ and $J/\psi \to \Lambda\bar{\Lambda}$ [30]. The differences after re-weighting efficiencies between data and MC simulation is (1.1 ± 0.9) % per $\Lambda\left(\bar{\Lambda}\right)$. To be conservative, the associated systematic uncertainty is assigned to be 2.0% per $\Lambda\left(\bar{\Lambda}\right)$.

Systematic uncetainties

Kinematic fit:

The systematic uncertainty due to kinematic fit is estimated by comparing the efficiency difference before and after applying the helix correction [31]. The correction factors for protons, kaon and pion are obtained with the control sample $\psi(3686) \to p\bar{p}\pi^0$, $\psi(3686) \to \gamma\chi_{c0}$ with $\chi_{c0} \to 2(K^+K^-)$ and $\psi(3686) \to \gamma\chi_{c0}$ with $\chi_{c0} \to 3(\pi^+\pi^-)$, and the correction factors are listed in Tab. 9. The efficiency difference is estimated to be 5.0%, which is taken as an item of systematic uncertainty. The χ^2 distributions before and after helix correction comparison with data are shown in Fig. 15.



Systematic uncetainties

Mass window:

The uncertainties are estimated by varying the mass window size by one standard deviation of its nominal value. The largest difference on branching fractions, listed in Tab. 10, are assigned as systematic uncertainties for each mass window condition.

Tab. 10: Systematic uncertainties of mass window requirements for $\psi(3686) \to pK^-\bar{\Lambda}\eta + c.c.$.

Mass window requirement $\left(GeV/c^2\right)$	Change $\left(MeV/c^2\right)$	Uncertainty (%)
$M_\eta^{rec} \notin (3.083, 3.114)$	+3	2.8

Background:

From topology information of the inclusive MC sample, the background level is determined to be 3.0% in the selected events. The contribution is considered in the PWA. The systematic uncertainty contribution from the background is taken as 3.0%.

Systematic uncetainties

MC statistics:

The uncertainty due to the limited MC statistics is considered as one source of systematic uncertainties. The detailed number is calculated via

$$\frac{1}{\sqrt{N}}\sqrt{\frac{1-\varepsilon}{\varepsilon}}, \tag{18}$$

where ε is the detection efficiency and N is the total number of generated signal MC events. In this analysis, we have $N = 2.8 \times 10^6$ and $\varepsilon = 4.56\%$, so the uncertainty is estimated to be 0.3%.

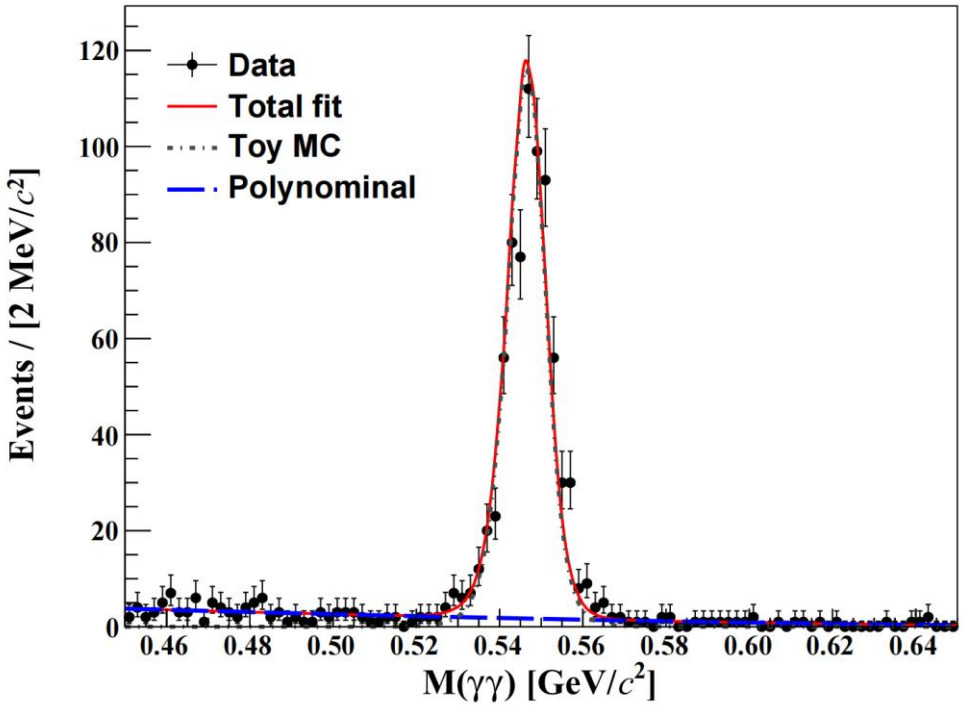
Total number of $\psi(3686)$:

The total number of ψ (3686) events is $(2712.4 \pm 14.3) \times 10^6$, and the uncertainty is assigned to be 0.5% [13, 14].

Systematic uncetainties

Sources	Uncertainty (%)
Tracking and photon efficiencies	4.0
PID efficiencies	2.0
$\Lambda\left(\bar{\Lambda}\right)$ reconstruction	2.0
Kinematic fit	5.0
η_{rec} mass window	2.8
Background	3.0
$\mathcal{B}\left(\bar{\Lambda} \to \bar{p}\pi^{+}\right)$	0.8
$\mathcal{B}\left(\eta \to \gamma\gamma\right)$	0.5
MC statistics	0.3
$N_{\psi(3686)}$	0.5
Total	8.2

Summary



- η signal yields:
  695 ± 27
- Detection efficiency:
  4.56% (From Toy MC)

- $B\left(\psi(2S) \to \Lambda(1405)\bar{\Lambda}(1670)\right) \cdot B(\Lambda(1405) \to pK^-) \cdot B\left(\bar{\Lambda}(1670) \to \bar{\Lambda}\eta\right)$
  $= (1.87 \pm 0.40 \pm 0.15) \times 10^{-6}$
- $B\left(\psi(2S) \to \Lambda(1670)\bar{\Lambda}(1670)\right) \cdot B(\Lambda(1670) \to pK^-) \cdot B\left(\bar{\Lambda}(1670) \to \bar{\Lambda}\eta\right)$
  $= (1.98 \pm 0.38 \pm 0.16) \times 10^{-6}$
- $B\left(\psi(2S) \to \Lambda(1520)\bar{\Lambda}\eta\right) \cdot B(\Lambda(1520) \to pK^-)$
  $= (3.03 \pm 0.44 \pm 0.25) \times 10^{-6}$
- $B\left(\psi(2S) \to N^+(1535)K^-\bar{\Lambda}\right) \cdot B(N^+(1535) \to p\eta)$
  $= (4.01 \pm 0.65 \pm 0.33) \times 10^{-6}$
- $B_{tot}\left(\psi(2S) \to pK^-\bar{\Lambda}\eta + c.c.\right)$
  $= (2.23 \pm 0.09 \pm 0.18) \times 10^{-5}$

Summary

- Using 2.7 billion $\psi(3686)$ events collected by BESIII detector, we do partial wave analysis for the decay $\psi(3686) \to pK^{-}\bar{\Lambda}\eta + c.c.$.
- The corresponding branching fraction are measured to be $(2.23 \pm 0.09 \pm 0.18) \times 10^{-5}$, where the first uncertainty is statistical, and the second uncertainty is systematic.
- Significant structures are observed on the invariant mass spectrum on M_{pK^-}, $M_{\bar{\Lambda}\eta}$ and $M_{p\eta}$. The corresponding branching fraction for each decay channel is measured.

Summary

Thanks for your attention!

Backup

$pK/\Lambda\eta$	J^P	Mass (MeV/c^2)	Width (MeV)	Status
$\Lambda(1405)$	$1/2^-$	$1405.1^{+1.3}_{-1.0}$	50.5 ± 2.0	****
$\Lambda(1520)$	$3/2^-$	1519.42 ± 0.19	15.73 ± 0.26	****
$\Lambda(1600)$	$1/2^+$	1600 ± 30	200 ± 50	****
$\Lambda(1670)$	$1/2^-$	1674 ± 4	30 ± 5	****
$\Lambda(1690)$	$3/2^-$	1690 ± 5	70 ± 10	****
$\Lambda(1800)$	$1/2^-$	1800 ± 50	200 ± 50	***
$\Lambda(1810)$	$1/2^+$	1790 ± 50	110 ± 60	***
$\Lambda(1820)$	$5/2^+$	1820 ± 5	80 ± 10	****
$\Lambda(1830)$	$5/2^-$	1825 ± 5	90 ± 30	****
$\Lambda(1890)$	$3/2^+$	1890 ± 20	120 ± 40	****

$p\Lambda/K\eta$	J^P	Mass (MeV/c^2)	Width (MeV)	Status
$K_1(1270)$	1^+	1253 ± 7	101 ± 12	•
$K_1(1400)$	1^+	1403 ± 7	174 ± 13	•
$K^*(1410)$	1^-	1414 ± 15	232 ± 21	•
$K_0^*(1430)$	0^+	1425 ± 50	270 ± 80	•
$K_2^*(1430)$	2^+	1427.3 ± 1.5	100.0 ± 2.2	•

$p\eta/K\Lambda$	J^P	Mass (MeV/c^2)	Width (MeV)	Status
$N(1520)$	$3/2^-$	1515 ± 5	110 ± 10	****
$N(1535)$	$1/2^-$	1530 ± 15	150 ± 25	****
$N(1650)$	$1/2^-$	1650 ± 15	125 ± 25	****
$N(1675)$	$5/2^-$	1675^{+5}_{-10}	145 ± 15	****
$N(1680)$	$5/2^+$	1685 ± 5	120^{+10}_{-5}	****
$N(1700)$	$3/2^-$	1720^{+80}_{-70}	200 ± 100	***
$N(1710)$	$1/2^+$	1710 ± 30	140 ± 60	****
$N(1720)$	$3/2^+$	1720^{+30}_{-40}	250^{+150}_{-100}	****
$N(1875)$	$3/2^-$	1875^{+45}_{-25}	200^{+50}_{-80}	***
$N(1880)$	$1/2^+$	1880 ± 50	300 ± 100	***
$N(1895)$	$1/2^-$	1895 ± 25	120^{+80}_{-40}	****
$N(1900)$	$3/2^+$	1920 ± 30	200^{+120}_{-100}	****

Backup

7.3 $\Lambda\left(\bar{\Lambda}\right)$ reconstruction

The efficiencies of $\Lambda\left(\bar{\Lambda}\right)$ reconstruction, including the tracking efficiencies of the $p\pi^-$ ($\bar{p}\pi^+$) pair, decay length cut, mass window cut, vertex fit and second vertex fit, are studied by using the control samples of $J/\psi \to pK^-\bar{\Lambda} + c.c.$ and $J/\psi \to \Lambda\bar{\Lambda}$ [30]. The differences after re-weighting efficiencies between data and MC simulation is $(1.1 \pm 0.9)\%$ per $\Lambda\left(\bar{\Lambda}\right)$. To be conservative, the associated systematic uncertainty is assigned to be 2.0% per $\Lambda\left(\bar{\Lambda}\right)$.

Backup

7.8 MC statistics

The uncertainty due to the limited MC statistics is considered as one source of systematic uncertainties. The detailed number is calculated via

$$\frac{1}{\sqrt{N}}\sqrt{\frac{1-\varepsilon}{\varepsilon}}, \tag{18}$$

where ε is the detection efficiency and N is the total number of generated signal MC events. In this analysis, we have $N = 2.8 \times 10^6$ and $\varepsilon = 4.56\%$, so the uncertainty is estimated to be 0.3%.