Study of the excited Ω^- baryon

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Motivation

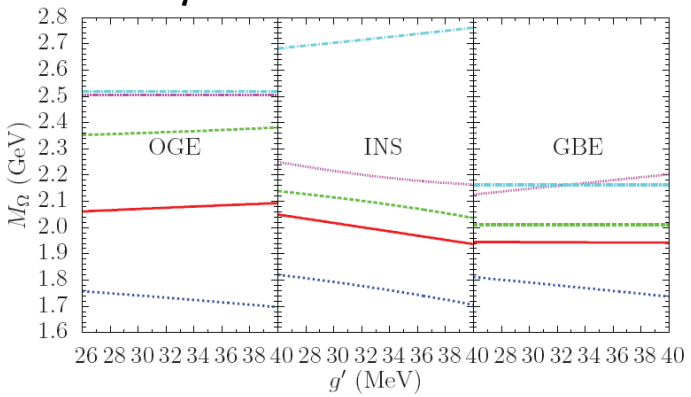
- Quark model predicts more baryons than those established in experiment (missing resonances problem).
- Only ground state of Ω^- has been experimentally established.
- The c.m. energy of BESIII data sets are from 2.0 GeV to 4.6 GeV, it provides a chance to study of the excited hyperons.

Particle	J^P	status	ΛK	$\Xi\pi$	$\Xi K\pi$	$\Xi(1530)K$	Other
$\Omega(1672)$	3/2−	****	√	√	--	--	Decays weekly
$\Omega(2250)$		***			√	√	
$\Omega(2380)$		**			√	√	ΞK^*
$\Omega(2470)$		**					$\Omega\pi\pi$

Motivation for Ω^* search

- Current lowest Ω^* is $\Omega(2250)$, which has about 600 MeV higher than ground state Ω. However, other lowest baryons have only about 100 MeV higher than their ground states. Is $\Omega(2250)$ the lowest Ω^*?
- Two different quark models have predicted the lowest Ω^*:
  - The traditional sss quark model: about 2000 MeV[1],
  - The sss[$s\bar{s}$] quark model[2]: about 1750~1840 MeV;
- It can be found in measurements of $\psi(3686)$ decays $\psi(3686) \to \bar{\Omega}\Omega^*$. The predicted mass constrain the decay channel: $\Omega^* \to \gamma\Omega$.

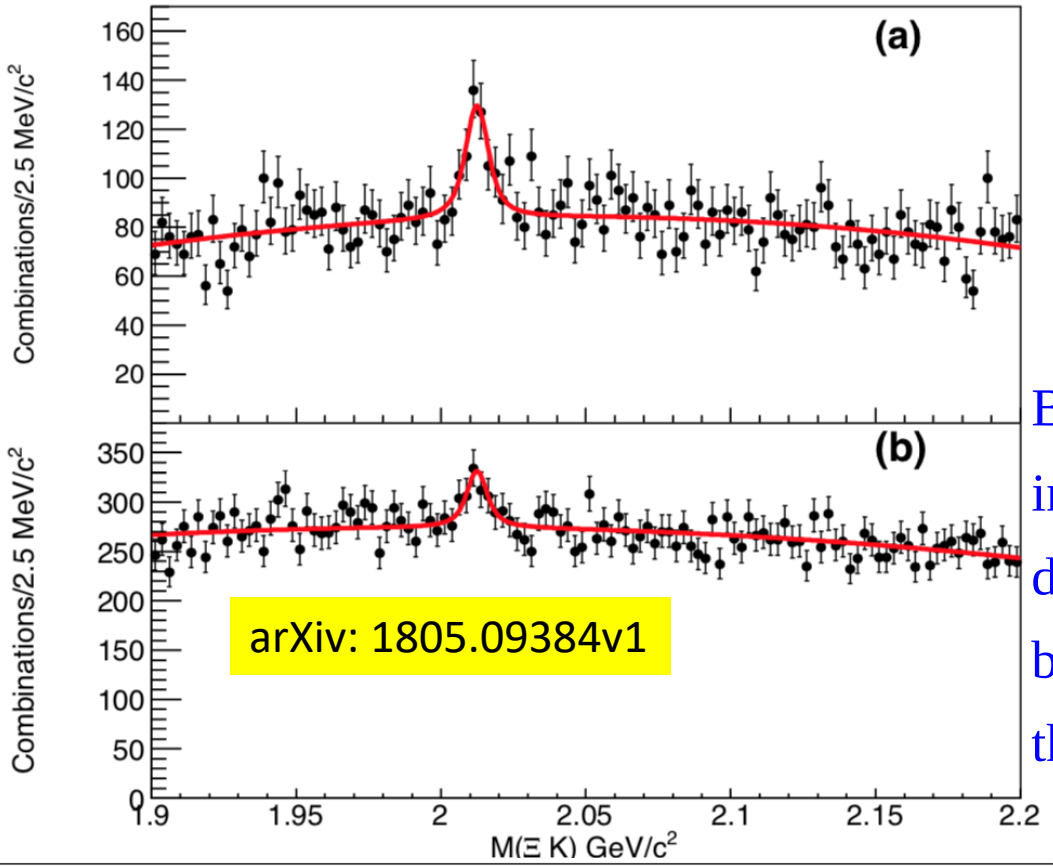
$\Omega\frac{3}{2}^+$	1635		
$\Omega^*\frac{1}{2}^-$	1950	2410	2490
$\Omega^*\frac{3}{2}^-$	2000	2440	2495
$\Omega^*\frac{5}{2}^-$	2490		
$\Omega^*\frac{1}{2}^+$	2220	2255	
$\Omega^*\frac{3}{2}^+$	2165	2280	2345
$\Omega^*\frac{5}{2}^+$	2280	2345	
$\Omega^*\frac{7}{2}^+$	2295		



[1] S. Capstick and N. Isgur, Phys. Rev. D 34, 2809 (1986)

[2] Yuan-An-Wei-Zou-Xu, Phys. Rev. C 87, 025205 (2013); An-Metsch-Zou, Phys. Rev. C 87, 065207 (2013)

Recent Ω^* observation at Belle



Data	Mode	Mass (MeV/c^2)	Yield	Γ(MeV)	χ^2/d.o.f.	n_σ
$\Upsilon(1S,2S,3S)$	Ξ^0K^-, $\Xi^-K^0_S$ (simultaneous)	2012.4 ± 0.7	$242 \pm 48,\ 279 \pm 71$	$6.4^{+2.5}_{-2.0}$	227/230	8.3
$\Upsilon(1S,2S,3S)$	Ξ^0K^-	2012.6 ± 0.8	239 ± 53	6.1 ± 2.6	115/114	6.9
$\Upsilon(1S,2S,3S)$	$\Xi^-K^0_S$	2012.0 ± 1.1	286 ± 87	6.8 ± 3.3	101/114	4.4
Other	Ξ^0K^-	2012.4 (Fixed)	209 ± 63	6.4 (Fixed)	102/116	3.4
Other	$\Xi^-K^0_S$	2012.4 (Fixed)	153 ± 89	6.4 (Fixed)	133/116	1.7

Belle has observed an Ω^* candidates into Ξ^0K^- and $\Xi^-K^0_S$. There are large discrepancies in the mass predictions, but the value is in general closer to the those for the $J^P = 3/2^-$ state.

$\Omega(2012)^-$

Data and MC samples

- Data samples: All $\psi(3686)$ data sample

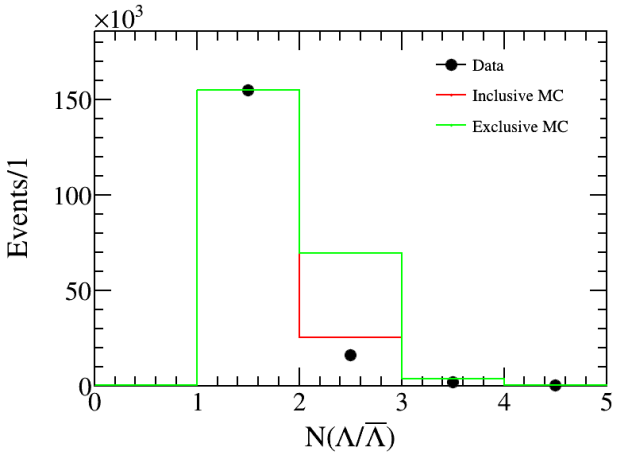
$\sqrt{s}$ (GeV)	$\mathcal{L}$ (pb^{-1})	BOSS Version	$\sqrt{s}$ (GeV)	$\mathcal{L}$ (pb^{-1})	BOSS Version
3.7730	2931.8	6.6.4.p02	4.2357	528.9	7.0.3
4.0076	482.0	7.0.3	4.2438	532.7	7.0.3
4.1784	3189.0	7.0.3	4.2580	825.7	7.0.3
4.1888	521.9	7.0.3	4.2667	529.3	7.0.3
4.1989	523.7	7.0.3	4.2777	174.5	7.0.3
4.2092	511.2	7.0.3	4.3583	539.8	7.0.3
4.2187	508.2	7.0.3	4.4156	1073.6	7.0.3
4.2263	1091.7	7.0.3	4.5995	566.9	7.0.3

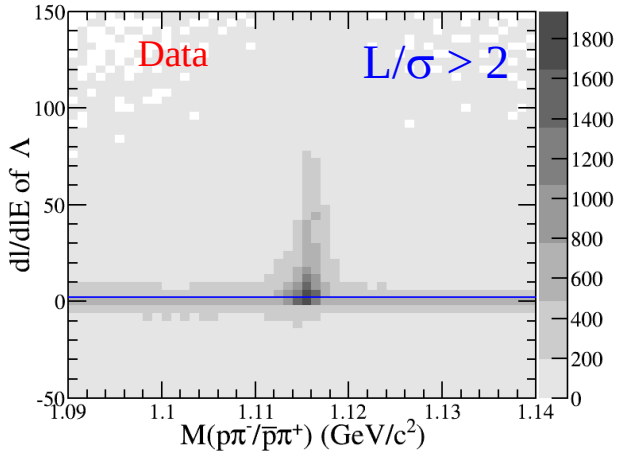
- Signal MC:
  - 0.1M $e^+e^- \to \gamma\Omega^-\bar{\Omega}^+, \Omega^- \to \Lambda K^-, \bar{\Omega}^+ \to anything$
  - 0.1M $e^+e^- \to \Omega^{*-}\bar{\Omega}^+, \Omega^{*-} \to \gamma\Omega^-, \bar{\Omega}^+ \to \bar{\Lambda}K^+, \Omega^- \to anything$

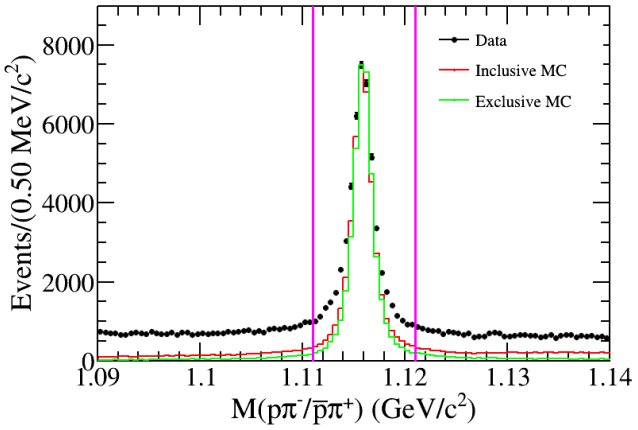
Event selection

- At least three charged tracks are required and their polar angles θ must satisfy $|\cos\theta| < 0.93$;
- $K^{\pm}$ list: $\mathcal{L}(\mathrm{K}) > \mathcal{L}(\boldsymbol{\pi})$, $\mathcal{L}(\mathrm{K}) > 0$;
- Proton list: $\mathcal{L}(\mathrm{p}) > 0$, $\mathcal{L}(\mathrm{p}) > \mathcal{L}(\mathrm{K})$ and $\mathcal{L}(\mathrm{p}) > \mathcal{L}(\boldsymbol{\pi})$;
- Loop the remaining charged tracks to find an charged pion and then reconstruct the $\Lambda/\bar{\Lambda}$;

$1.111 < M(p\pi^-) < 1.121$ GeV/c^2



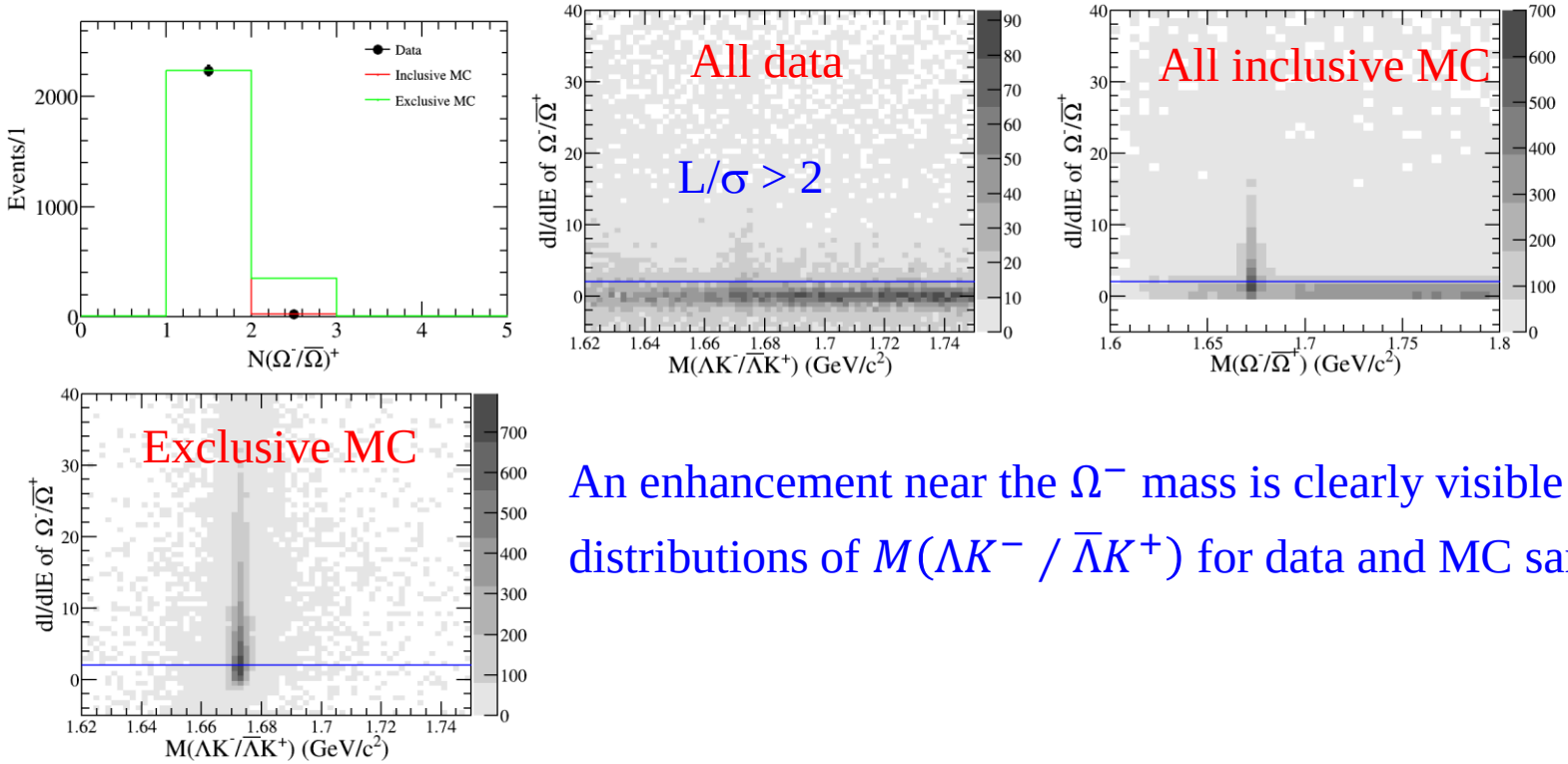




- The decay lengths of $\Lambda/\bar{\Lambda}$ must satisfy $L/\sigma > 2$, the signal region of $M(p\pi^-)$ is $1.111 < M(p\pi^-) < 1.121$ GeV/c^2;

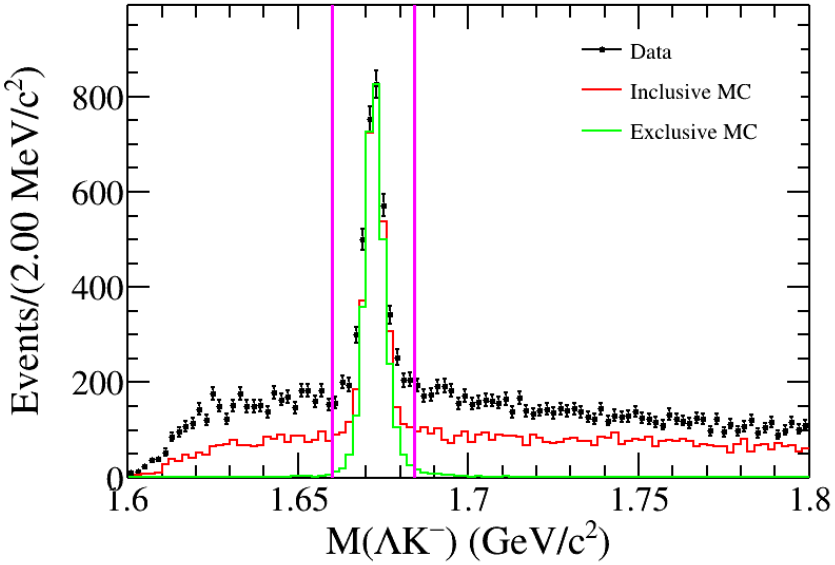
Event selection

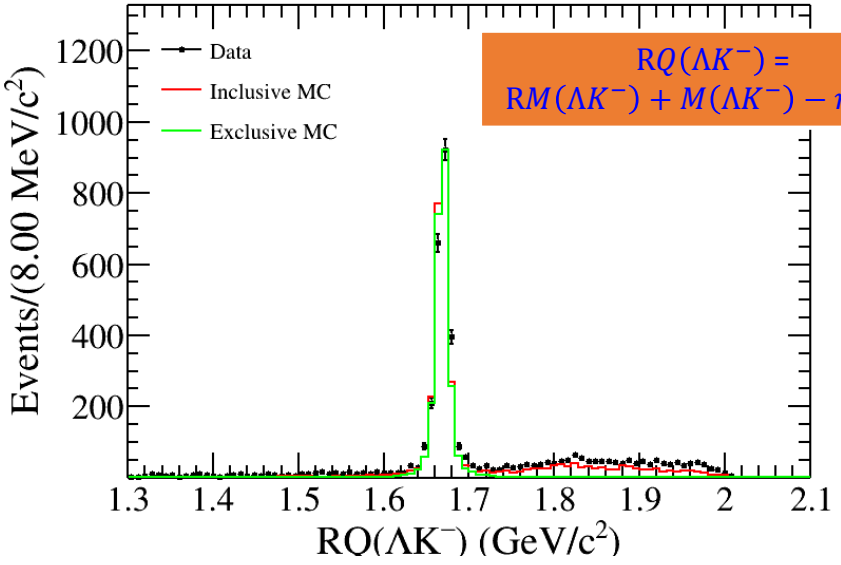
- Loop all of K^-/K^+ and $\Lambda/\bar{\Lambda}$ candidates and perform a vertex fit for $K^-\Lambda/K^+\bar{\Lambda}$ and a secondary vertex fit for $\Omega^-/\bar{\Omega}^+$;
- The decay lengths of Ω^- must satisfy L/σ > 2. If there is more than one Ω^- candidates, the candidate with minimum χ^2 is selected.



An enhancement near the Ω^- mass is clearly visible in the distributions of $M(\Lambda K^- / \bar{\Lambda} K^+)$ for data and MC samples.

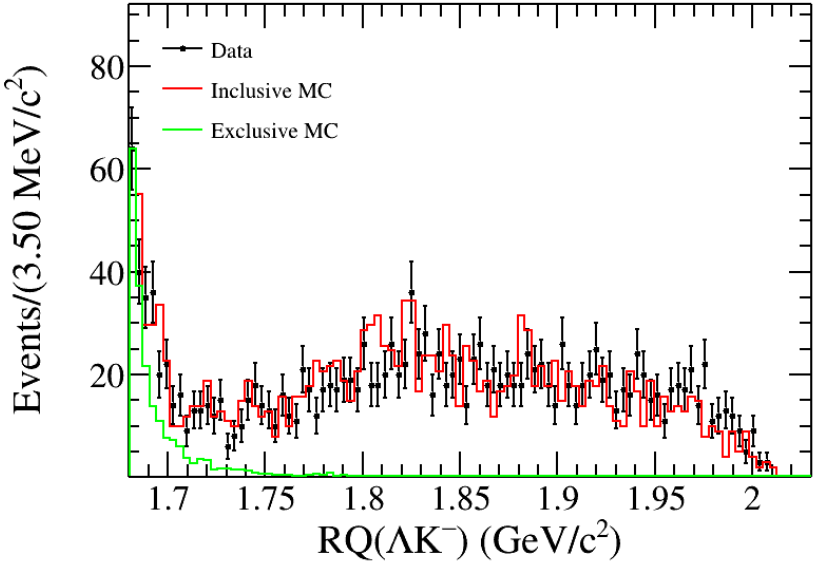
Results of $\psi(3686)$ data



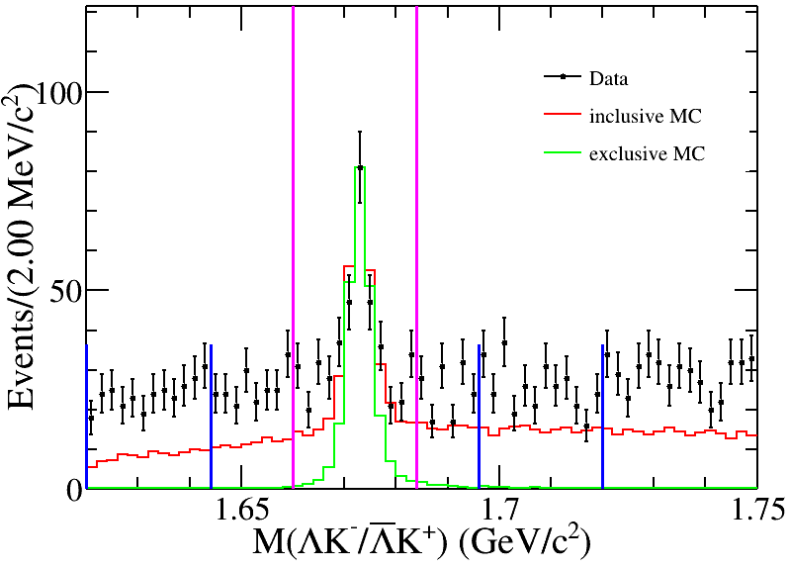


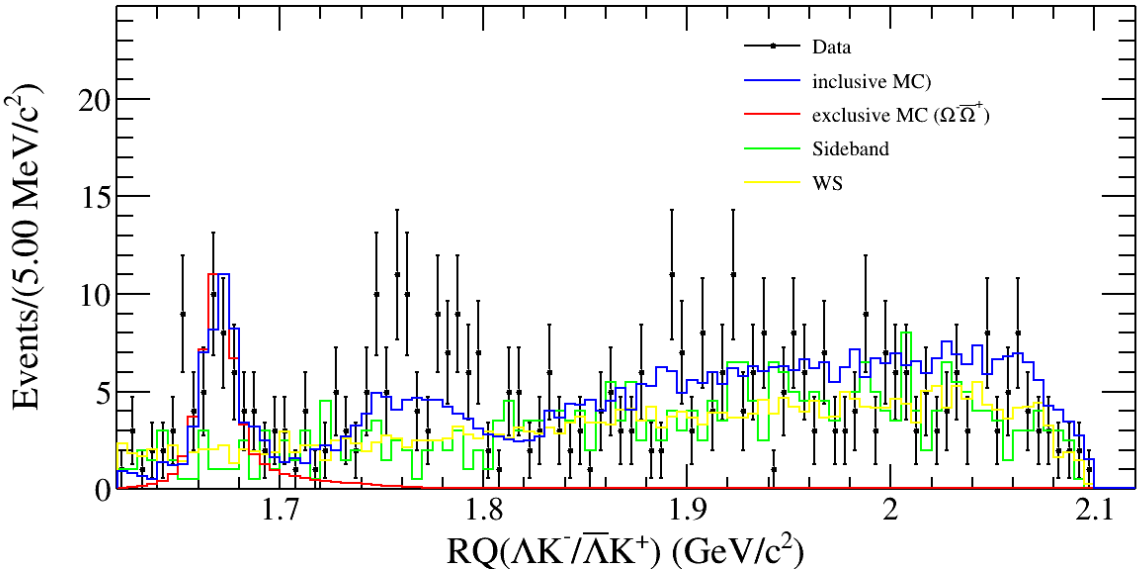
$RQ(\Lambda K^-) = RM(\Lambda K^-) + M(\Lambda K^-) - m(\Omega^-)$

- No significant Ω^* is observed the recoil mass of ΛK^-;
- The distributions of RQ(ΛK^-) for data and inclusive MC are consistent with each other.



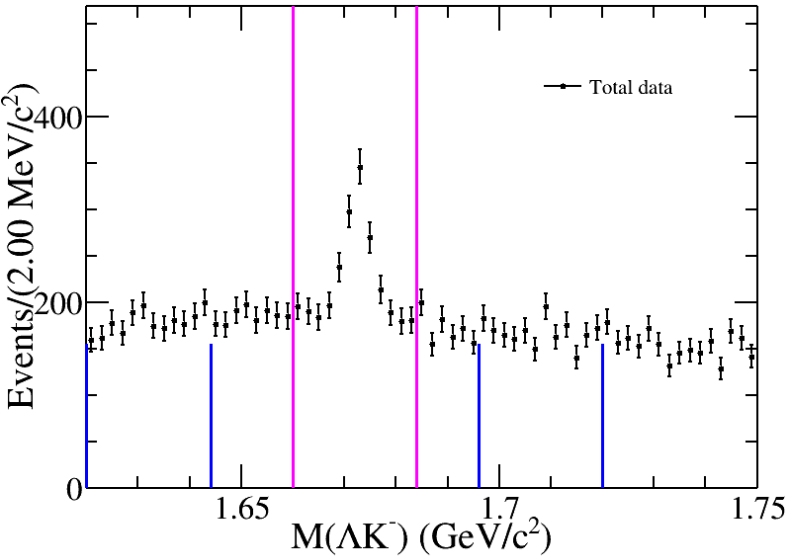
Results of $\psi(3770)$ data



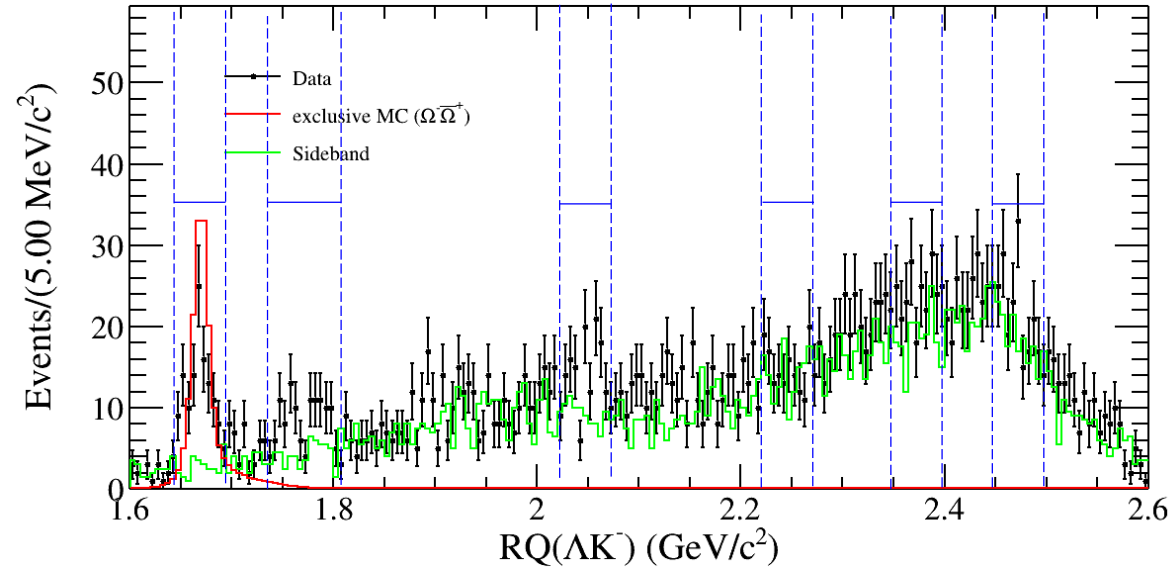


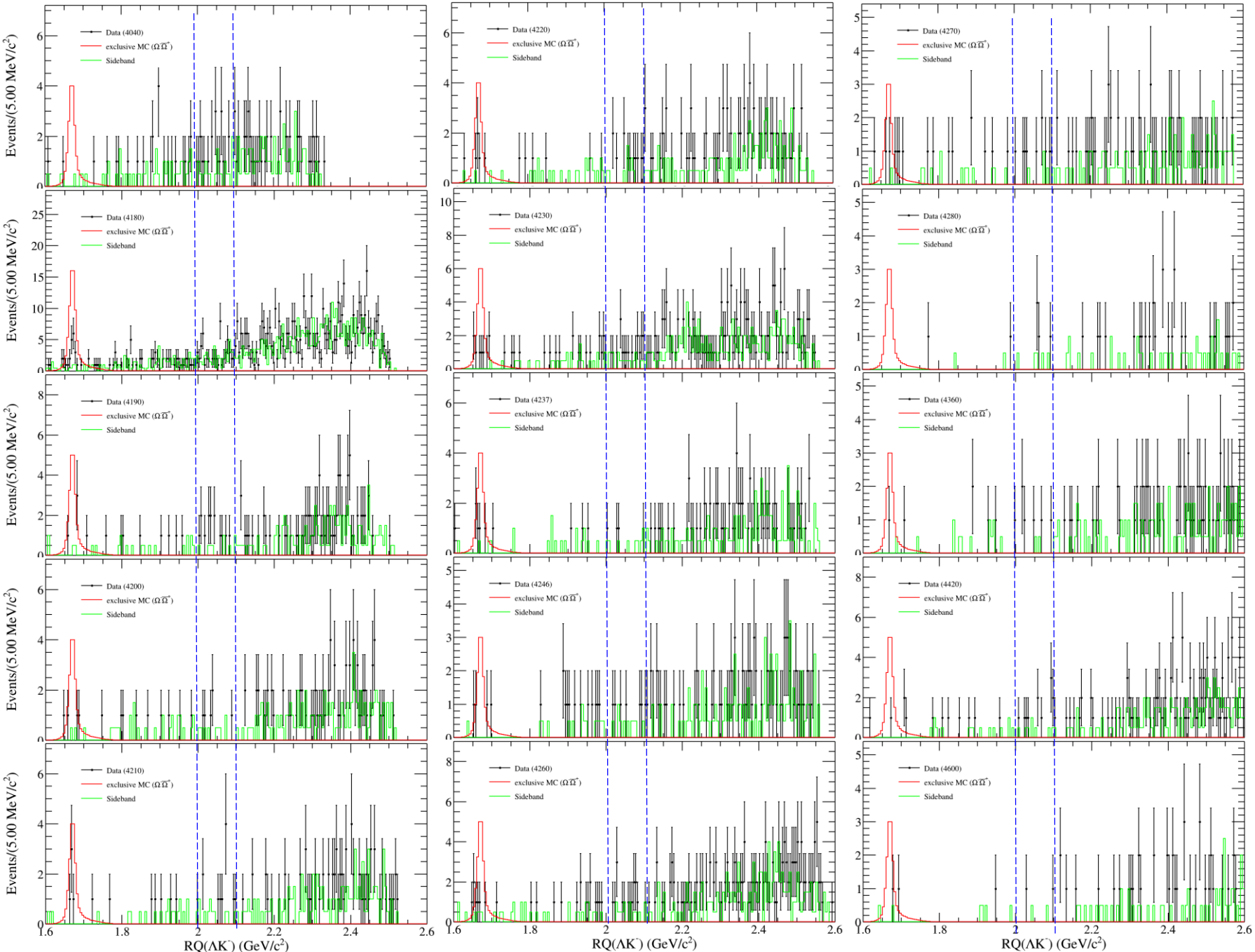
- A clear Ω^- signal in the distributions of M(ΛK^-);
- An broaden enhancements are clearly visible in both data and inclusive MC, which is from $\gamma\psi(3686)$;
- NO significant $\Omega(2012)^-$ is observed.

Results of total data



- Some small discrepancies around the possible Ω^{*-} masses for all data samples, while the significance is very small;
- Here is the result for all data samples, that possibly means we only can give the upper limits for these Ω^{*-} states.




Data (4040)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Data (4220)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Data (4270)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Data (4180)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Data (4230)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Data (4280)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Data (4190)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Data (4237)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Data (4360)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Data (4200)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Data (4246)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Data (4420)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Data (4210)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Data (4260)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Data (4600)
exclusive MC ($\Omega\bar{\Omega}^+$)
Sideband
Events/(5.00 MeV/c^2)
RQ(ΛK^-) (GeV/c^2)

Summary and to do list

- We search the excited Ω^- baryon for BESIII data samples, while no significant signals are observed.

- We will optimize the event selection to improve the significance. Any suggestions are welcome.
- Currently, only the upper limits for all possible Ω^- baryon will be provided if the significant can not be improved in the future.
- Include this result to the memo of $e^+e^- \to \Omega^-\overline{\Omega}^+$ cross section measurement?