

Improve measurement of decay parameters of Λ in $J/\psi \rightarrow \Lambda \bar{\Lambda}$

Jianyu Zhang¹, Haibo Li²

Institute of High Energy Physics

SEP-6, 2018

- Motivation
- Data Sets
- Event Selection
- Background Study

Motivation I

The differential-cross-section distribution

$$d\sigma \propto \mathcal{W}(\boldsymbol{\xi}) d\cos\theta d\Omega_1 d\Omega_2.$$

The differential-distribution function $\mathcal{W}(\boldsymbol{\xi})$ can be expressed as,

$$\begin{aligned} \mathcal{W}(\boldsymbol{\xi}) = & \mathcal{F}_0(\boldsymbol{\xi}) + \alpha\mathcal{F}_5(\boldsymbol{\xi}) \\ & + \alpha_1\alpha_2 \left(\mathcal{F}_1(\boldsymbol{\xi}) + \sqrt{1-\alpha^2} \cos(\Delta\Phi)\mathcal{F}_2(\boldsymbol{\xi}) + \alpha\mathcal{F}_6(\boldsymbol{\xi}) \right) \\ & + \sqrt{1-\alpha^2} \sin(\Delta\Phi) (\alpha_1\mathcal{F}_3(\boldsymbol{\xi}) + \alpha_2\mathcal{F}_4(\boldsymbol{\xi})), \end{aligned}$$

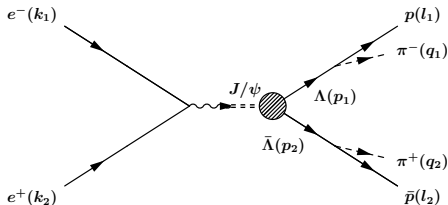


Figure: Graph describing the reaction $e^+e^- \rightarrow \Lambda(\rightarrow p\pi^-)\bar{\Lambda}(\rightarrow \bar{p}\pi^+)$.

Motivation II

$$\mathcal{F}_0(\xi) = 1$$

$$\mathcal{F}_1(\xi) = \sin^2\theta \sin\theta_1 \sin\theta_2 \cos\phi_1 \cos\phi_2 + \cos^2\theta \cos\theta_1 \cos\theta_2$$

$$\mathcal{F}_2(\xi) = \sin\theta \cos\theta (\sin\theta_1 \cos\theta_2 \cos\phi_1 + \cos\theta_1 \sin\theta_2 \cos\phi_2)$$

$$\mathcal{F}_3(\xi) = \sin\theta \cos\theta \sin\theta_1 \sin\phi_1$$

$$\mathcal{F}_4(\xi) = \sin\theta \cos\theta \sin\theta_2 \sin\phi_2$$

$$\mathcal{F}_5(\xi) = \cos^2\theta$$

$$\mathcal{F}_6(\xi) = \cos\theta_1 \cos\theta_2 - \sin^2\theta \sin\theta_1 \sin\theta_2 \sin\phi_1 \sin\phi_2.$$

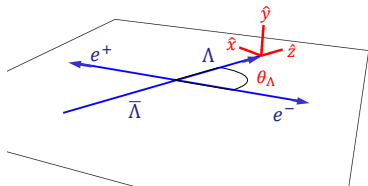


Figure: Kinematics of the reaction $e^+e^- \rightarrow \Lambda \bar{\Lambda}$ in the overall center-of-mass system.

- High precise measurements of hyperon and anti-hyperon decay parameters provide a test of CP symmetry.
[A. Pais, Phys. Rev. Lett. 3, 242 \(1959\).](#)
- The observable of CP asymmetry is defined by $A_Y = \frac{\alpha_Y + \alpha_{\bar{Y}}}{\alpha_Y - \alpha_{\bar{Y}}}$. None zero value of A_Y represents CP Violation.

- Analysis BOSS Version : 6.6.4.p01
- Data Sample : 1.310×10^9 J/ψ @ $\sqrt{s} = 3.097$ GeV in 2009 (0.224×10^9) and 2012 (1.086×10^9)
- Inclusive Monte Carlo Sample : (1.225×10^9) inclusive MC for J/ψ decay
- Signal Monte Carlo Sample (PHSP Model) :

5×10^5 events for $J/\psi \rightarrow \Lambda \bar{\Lambda}, \Lambda \rightarrow p\pi^-, \bar{\Lambda} \rightarrow \bar{p}\pi^+$

Event Selection I

- (1) Good charged tracks selection:
 - polar angle $|\cos \theta| < 0.93$
 - good charged tracks equal or larger than 4
- (2) Proton candidate: $p_p > 0.5\text{GeV}/c$
- (3) Pion candidate: $p_\pi < 0.5\text{GeV}/c$
- (4) Lambda(bar) candidate:
 - primary vertex fit $\chi^2 < 200$
 - $M_{p\pi^-} \in (1.11107, 1.12052)$
 - $M_{\bar{p}\pi^+} \in (1.11110, 1.12051)$
- (5) J/ψ candidate: $\chi_{4C}^2 < 60$

Event Selection II

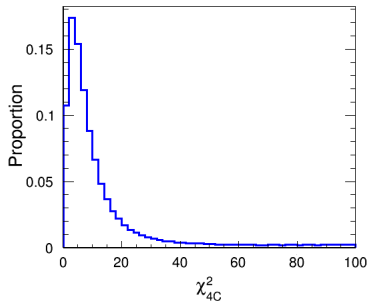


Figure: χ_{4C}^2 distribution of inclusive Monte Carlo

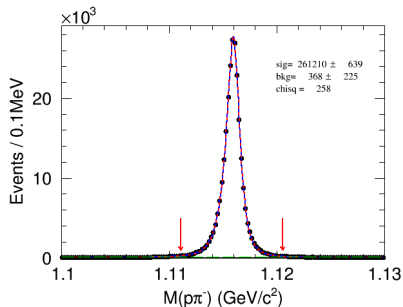


Figure: $M_{p\pi^-}$ distribution of inclusive Monte Carlo

Background Study

There are approximately 0.7 % peak background events and 0.08 % other background events pass the selection.

No.	decay chain	final states	iTopology	nEvt	nTot
0	$J/\psi \rightarrow \Lambda\bar{\Lambda}, \Lambda \rightarrow p\pi^-, \bar{\Lambda} \rightarrow \pi^+\bar{p}$	$\pi^-\bar{p}\pi^+p$	0	254133	254133
1	$J/\psi \rightarrow \Lambda\Sigma^0, \Lambda \rightarrow p\pi^-, \Sigma^0 \rightarrow \gamma\bar{\Lambda}, \bar{\Lambda} \rightarrow \pi^+\bar{p}$	$\pi^-\bar{p}\pi^+\gamma p$	2	801	254934
2	$J/\psi \rightarrow \Sigma^0\bar{\Lambda}, \Sigma^0 \rightarrow \Lambda\gamma, \bar{\Lambda} \rightarrow \pi^+\bar{p}, \Lambda \rightarrow p\pi^-$	$\pi^-\bar{p}\pi^+\gamma p$	1	784	255718
3	$J/\psi \rightarrow \Lambda\gamma\bar{\Lambda}, \Lambda \rightarrow p\pi^-, \bar{\Lambda} \rightarrow \pi^+\bar{p}$	$\pi^-\bar{p}\pi^+\gamma p$	7	307	256025
4	$J/\psi \rightarrow p\pi^+\pi^-\bar{p}$	$\pi^-\bar{p}\pi^+p$	5	116	256141
5	$J/\psi \rightarrow \Delta^{++}\pi^-\bar{p}, \Delta^{++} \rightarrow p\pi^+$	$\pi^-\bar{p}\pi^+p$	6	35	256176
6	$J/\psi \rightarrow \Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \rightarrow p\pi^+, \bar{\Delta}^{--} \rightarrow \pi^-\bar{p}$	$\pi^-\bar{p}\pi^+p$	4	23	256199
7	$J/\psi \rightarrow \eta_c\gamma, \eta_c \rightarrow \Lambda\bar{\Lambda}, \Lambda \rightarrow p\pi^-, \bar{\Lambda} \rightarrow \pi^+\bar{p}$	$\pi^-\bar{p}\pi^+\gamma p$	10	16	256215
8	$J/\psi \rightarrow p\pi^+\bar{\Delta}^{--}, \bar{\Delta}^{--} \rightarrow \pi^-\bar{p}$	$\pi^-\bar{p}\pi^+p$	16	12	256227
9	$J/\psi \rightarrow \Lambda\bar{\Lambda}, \Lambda \rightarrow p\gamma_{FSR}\pi^-, \bar{\Lambda} \rightarrow \pi^+\bar{p}$	$\pi^-\bar{p}\pi^+p$	12	8	256235
10	$J/\psi \rightarrow \Lambda\bar{\Lambda}, \Lambda \rightarrow p\pi^-, \bar{\Lambda} \rightarrow \pi^+\bar{p}$	$\pi^-\bar{p}\pi^+\gamma p$	3	8	256243
11	$J/\psi \rightarrow \Lambda\bar{\Lambda}, \Lambda \rightarrow p\gamma\pi^-, \bar{\Lambda} \rightarrow \pi^+\bar{p}$	$\pi^-\bar{p}\pi^+\gamma p$	9	6	256249
12	$J/\psi \rightarrow \Lambda\bar{\Lambda}, \Lambda \rightarrow p\pi^-, \bar{\Lambda} \rightarrow \pi^+\gamma_{FSR}\bar{p}$	$\pi^-\bar{p}\pi^+p$	14	5	256254
13	$J/\psi \rightarrow \Delta^0\bar{\Delta}^0, \Delta^0 \rightarrow p\pi^-, \bar{\Delta}^0 \rightarrow \pi^+\bar{p}$	$\pi^-\bar{p}\pi^+p$	15	5	256259
14	$J/\psi \rightarrow \Lambda\bar{\Lambda}, \Lambda \rightarrow p\pi^-, \bar{\Lambda} \rightarrow \nu_\mu\mu^+\bar{p}$	$\mu^+\pi^-\bar{p}\nu_\mu p$	11	4	256263
15	$J/\psi \rightarrow \Lambda\bar{\Lambda}, \Lambda \rightarrow p\mu^-\bar{\nu}_\mu, \bar{\Lambda} \rightarrow \pi^+\bar{p}$	$\bar{\nu}_\mu\bar{p}\mu^-\pi^+p$	13	4	256267
16	$J/\psi \rightarrow b_1^+\pi^-, b_1^+ \rightarrow \pi^+\gamma$	$\pi^-\pi^+\gamma$	21	1	256268
17	$J/\psi \rightarrow \Lambda\bar{\Lambda}, \Lambda \rightarrow p\pi^-, \bar{\Lambda} \rightarrow \nu_e e^+\bar{p}$	$e^+\pi^-\bar{p}\nu_e p$	19	1	256269
18	$J/\psi \rightarrow \Delta^{++}\gamma_{FSR}\pi^-\bar{p}, \Delta^{++} \rightarrow p\pi^+$	$\pi^-\bar{p}\pi^+p$	17	1	256270
19	$J/\psi \rightarrow p\pi^-\bar{\Delta}^0, \bar{\Delta}^0 \rightarrow \pi^+\bar{p}$	$\pi^-\bar{p}\pi^+p$	20	1	256271
20	$J/\psi \rightarrow \Delta^0\pi^+\bar{p}, \Delta^0 \rightarrow p\pi^-$	$\pi^-\bar{p}\pi^+p$	8	1	256272
21	$J/\psi \rightarrow \Sigma^0\bar{\Lambda}, \Sigma^0 \rightarrow \Lambda\gamma, \bar{\Lambda} \rightarrow \pi^+\bar{p}, \Lambda \rightarrow p\mu^-\bar{\nu}_\mu$	$\bar{\nu}_\mu\bar{p}\mu^-\pi^+\gamma p$	18	1	256273
22	$J/\psi \rightarrow \Sigma^0\bar{\Sigma}^0, \Sigma^0 \rightarrow \Lambda\gamma, \bar{\Sigma}^0 \rightarrow \gamma\bar{\Lambda}, \Lambda \rightarrow p\pi^-, \bar{\Lambda} \rightarrow \pi^+\bar{p}$	$\pi^-\bar{p}\pi^+\gamma p$	22	1	256274

Figure: The topology of remaining background events from 1225 million J/ψ inclusive MC sample

Thank You!