Study of $\eta_c \rightarrow \Lambda\bar{\Lambda}$ in J/ψ radiative decay

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OUTLINE

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- Data sets and MC samples
- Event selection
- Background study
- Summary

Motivation

- Heavy $q\bar{q}$ bound-state decays are supposed to be a good testing ground for perturbative QCD, such as η_c, J/ψ and so on.
- Hadronic decays of η_c have been studied by MARKIII, BESII/III, and other experiments. The branching fractions of η_c still have large errors. Such as:

$$\eta_c \rightarrow \begin{cases} \Lambda\bar{\Lambda} : (1.09 \pm 0.24) \times 10^{-3} \\ \Sigma^+\bar{\Sigma}^- : (2.1 \pm 0.6) \times 10^{-3} \\ \vdots \end{cases}$$

pdg2018

Data sets and MC sample

- Data: 1.31×10^9 (2009 and 2012), 4.60×10^9 (2017 and 2018)
- Inclusive MC:~100 million
- Exclusive MC:
  - $\mathrm{J}/\psi \rightarrow \gamma\eta_c,\ \ \eta_c \rightarrow \Lambda\overline{\Lambda},\ \ \Lambda\bar{p}\pi^+,\ \ \overline{\Lambda}p\pi^-$
  - $\mathrm{J}/\psi \rightarrow \Lambda\overline{\Lambda}\ ,\gamma\Lambda\overline{\Lambda},\pi^0\Lambda\overline{\Lambda}\ ,\overline{\Sigma}^0\left(\gamma\overline{\Lambda}\right)\Lambda + c.c,\cdots$
- Boss version: 7.0.3

Event selection

- **Initial selection**

  - **Charged track :** N_{good} = 4 with net Charge = 0

    1) No requirements for Vz and Vr
    2) PID is used to identify proton and pion.
    3) Λ reconstruction: secondary-vertex reconstruction

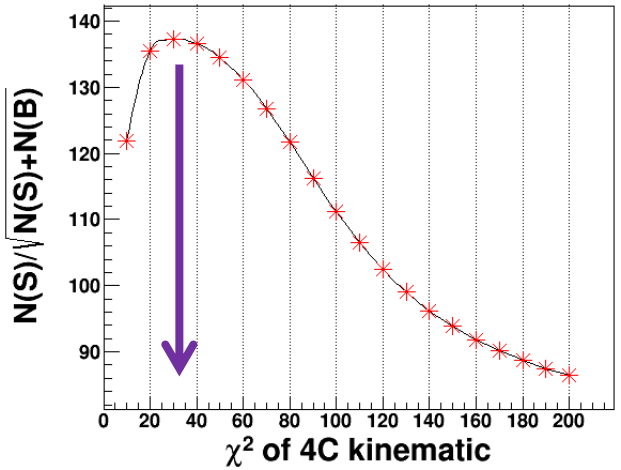
  - **Neutral track: $N_\gamma \geq 1$**

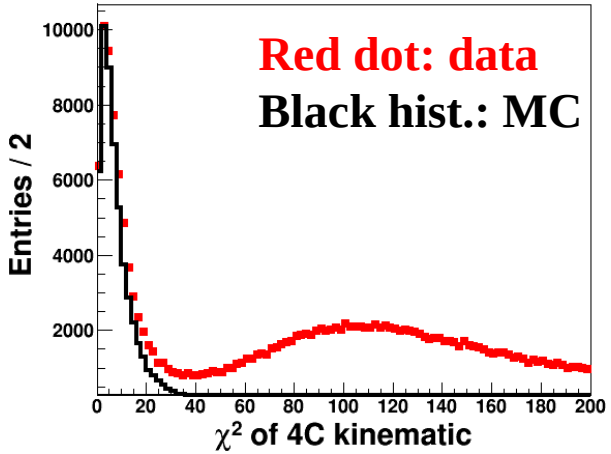
    1) $E_\gamma > 25$ MeV (Barrel), $E_\gamma > 50$ MeV (End cap)
    2) $\theta(\gamma, \ \bar{p}) > 30°$, $\theta(\gamma, \ p、\ \pi^{\pm}) > 20°$

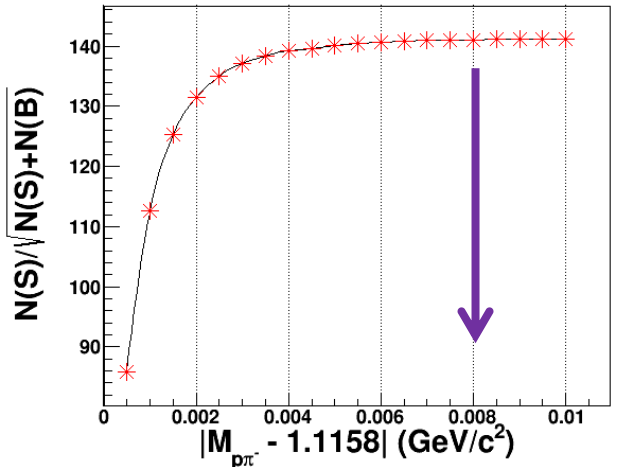
  - **The 4C kinematic fit (J/ψ→γΛ$\bar{\Lambda}$ hypothesis)**

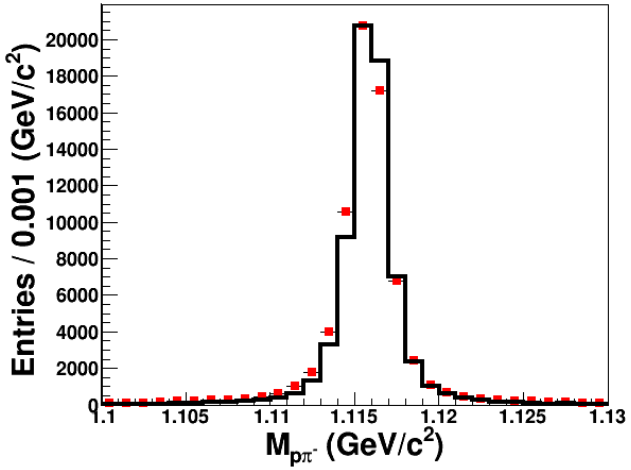
Event selection

- **Further selection**
- $S / \sqrt{S + B}$ is used to optimize the selection





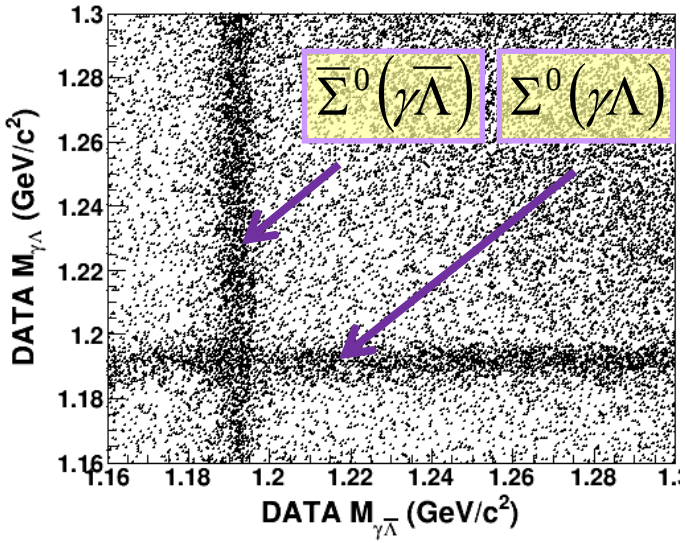


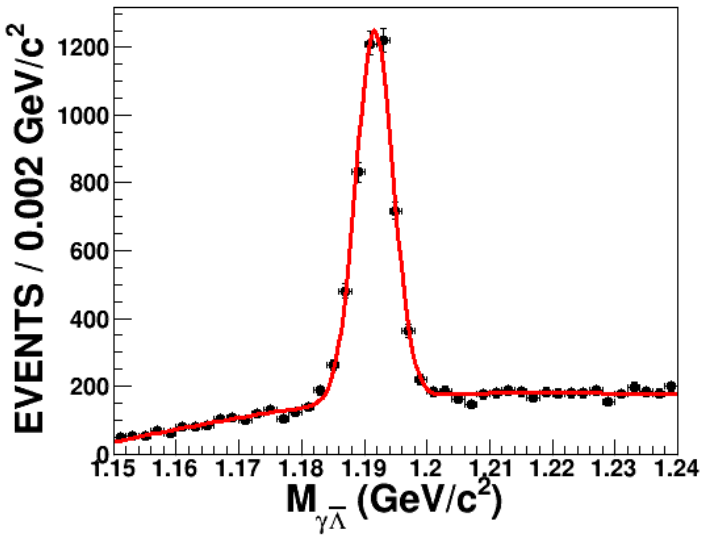


- $\chi^2 < 30$
- $\left|M_{p\pi} - 1.1158\right| < 0.008\ \mathrm{GeV/c^2}$

Event selection

- **Further selection**
- $S / \sqrt{S + B}$ is used to optimize the selection





$M_{\gamma\Lambda} = 1191.64 \pm 0.06$ MeV/c^2

$\sigma_{\gamma\Lambda} = 3.69 \pm 0.06$ MeV/c^2

- $\chi^2 < 30$
- $|M_{p\pi} - 1.1158| < 0.008$ GeV/c^2
- $|M_{\lambda\Lambda(\bar{\Lambda})} - 1.192| > 0.012$ GeV/c^2

ε=12.13%

Background study

No.	decay chain	final states	iTopo	nEvt	nTot
0	$J/\psi \to \bar{\Lambda}\gamma\Lambda,\ \bar{\Lambda} \to \bar{p}\pi^+,\ \Lambda \to \pi^- p,$	$J/\psi \to \gamma p\pi^+\pi^-\bar{p}$	0	1832	1832
1	$J/\psi \to \gamma\eta_c,\ \eta_c \to \bar{\Lambda}\Lambda,\ \bar{\Lambda} \to \bar{p}\pi^+,\ \Lambda \to \pi^- p,$	$J/\psi \to \gamma p\pi^+\pi^-\bar{p}$	1	62	1894
2	$J/\psi \to \bar{\Lambda}\Sigma^0,\ \bar{\Lambda} \to \bar{p}\pi^+,\ \Sigma^0 \to \gamma\Lambda,\ \Lambda \to \pi^- p,$	$J/\psi \to \gamma p\pi^+\pi^-\bar{p}$	2	32	1926
3	$J/\psi \to \bar{\Sigma}^0\Lambda,\ \bar{\Sigma}^0 \to \bar{\Lambda}\gamma,\ \Lambda \to \pi^- p,\ \bar{\Lambda} \to \bar{p}\pi^+,$	$J/\psi \to \gamma p\pi^+\pi^-\bar{p}$	3	26	1952
4	$J/\psi \to \bar{\Sigma}^0\Sigma^0,\ \bar{\Sigma}^0 \to \bar{\Lambda}\gamma,\ \Sigma^0 \to \gamma\Lambda,\ \Lambda \to \pi^- p,\ \bar{\Lambda} \to \bar{p}\pi^+,$	$J/\psi \to \gamma\gamma p\pi^+\pi^-\bar{p}$	4	17	1969
5	$J/\psi \to \bar{\Lambda}\Lambda,\ \bar{\Lambda} \to \bar{p}\pi^+,\ \Lambda \to \pi^- p,$	$J/\psi \to p\pi^+\pi^-\bar{p}$	6	14	1983
6	$J/\psi \to \bar{\Lambda}\pi^0\Lambda,\ \bar{\Lambda} \to \bar{p}\pi^+,\ \Lambda \to \pi^- p,$	$J/\psi \to \gamma\gamma p\pi^+\pi^-\bar{p}$	12	2	1985
7	$J/\psi \to \bar{\Lambda}\pi^-\Sigma^+,\ \bar{\Lambda} \to \bar{p}\pi^+,\ \Sigma^+ \to \gamma p,$	$J/\psi \to \gamma p\pi^+\pi^-\bar{p}$	7	1	1986
8	$J/\psi \to \bar{\Sigma}^-\pi^+\Lambda,\ \bar{\Sigma}^- \to \bar{p}\gamma,\ \Lambda \to \pi^- p,$	$J/\psi \to \gamma p\pi^+\pi^-\bar{p}$	8	1	1987
9	$J/\psi \to \bar{\Sigma}^-\Sigma^{*+},\ \bar{\Sigma}^- \to \bar{p}\pi^0,\ \Sigma^{*+} \to \pi^+\Lambda,\ \Lambda \to \pi^- p,$	$J/\psi \to \gamma\gamma p\pi^+\pi^-\bar{p}$	9	1	1988
10	$J/\psi \to \gamma\eta_c,\ \eta_c \to \bar{p}\pi^-\pi^+ p,$	$J/\psi \to \gamma p\pi^+\pi^-\bar{p}$	10	1	1989
11	$J/\psi \to \bar{\Lambda}\Sigma^{*0},\ \bar{\Lambda} \to \bar{p}\pi^+,\ \Sigma^{*0} \to \pi^0\Lambda,\ \Lambda \to \pi^- p,$	$J/\psi \to \gamma\gamma p\pi^+\pi^-\bar{p}$	11	1	1990
12	$J/\psi \to \bar{\Sigma}^{*-}\Sigma^+,\ \bar{\Sigma}^{*-} \to \bar{\Lambda}\pi^-,\ \Sigma^+ \to \gamma p,\ \bar{\Lambda} \to \bar{p}\pi^+,$	$J/\psi \to \gamma p\pi^+\pi^-\bar{p}$	5	1	1991
13	$J/\psi \to \bar{\Delta}^{++}\pi^0\Delta^{++},\ \bar{\Delta}^{++} \to \bar{p}\pi^-,\ \Delta^{++} \to \pi^+ p,$	$J/\psi \to \gamma\gamma p\pi^+\pi^-\bar{p}$	13	1	1992

Table 1:

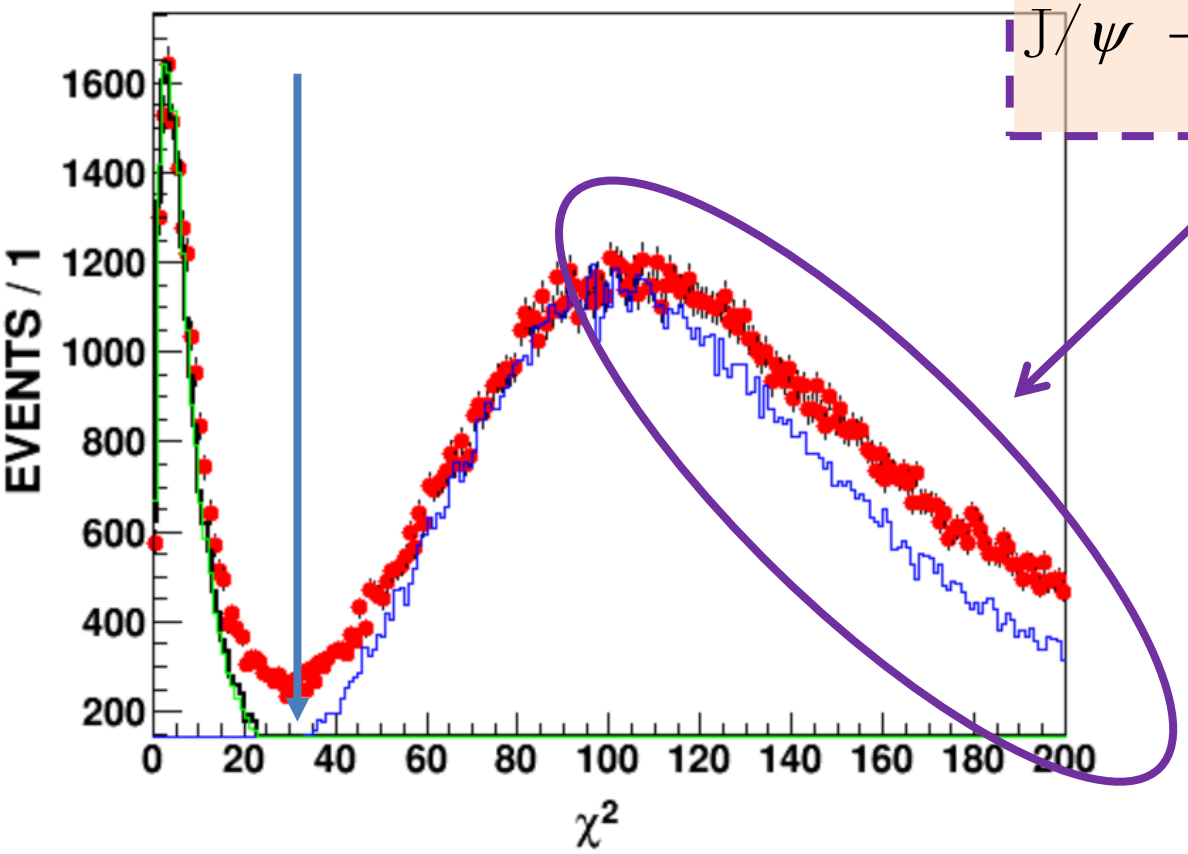
Main background

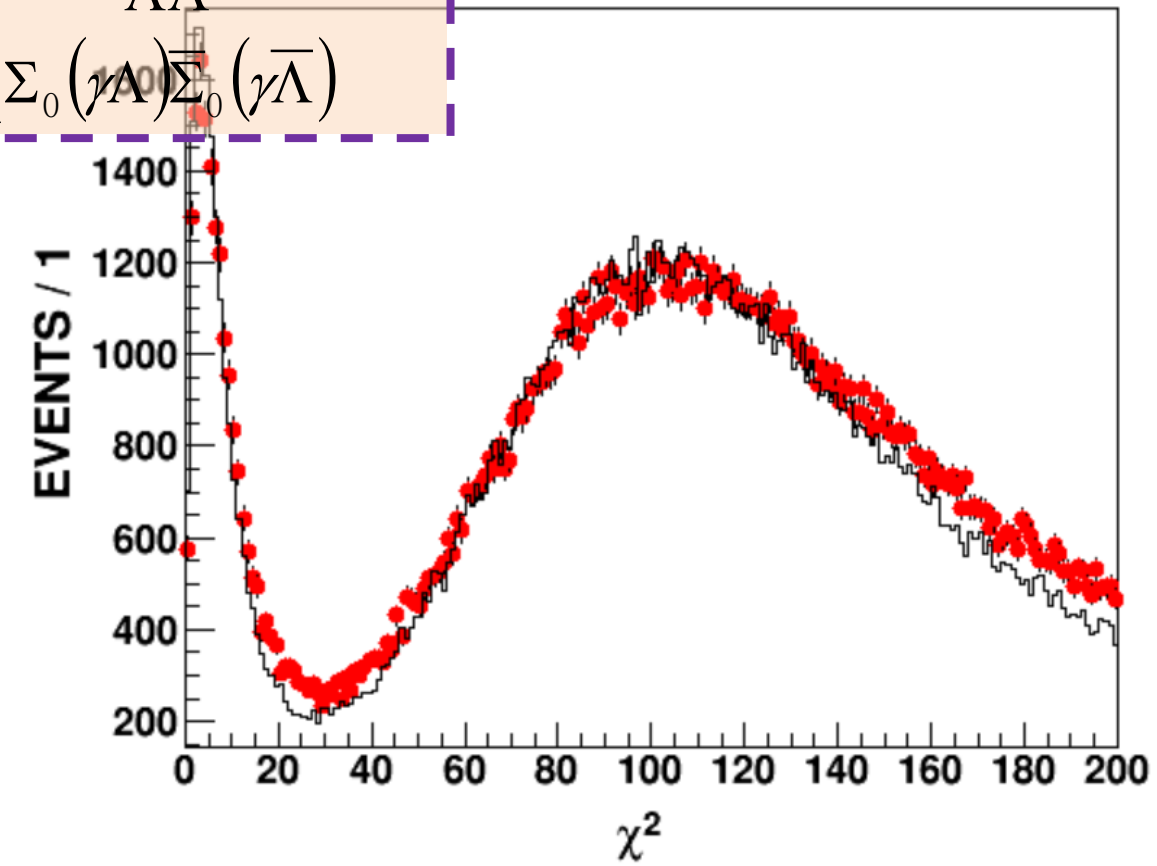
$$\mathrm{J}/\psi \to \Lambda\overline{\Lambda},\ \pi^0\Lambda\overline{\Lambda},\ \overline{\Sigma}^0\left(\gamma\overline{\Lambda}\right)\Lambda + c.c,\ \Sigma^0\left(\gamma\Lambda\right)\overline{\Sigma}^0\left(\gamma\overline{\Lambda}\right),\ \overline{\Lambda}(1520)\Lambda + c.c$$

Background study

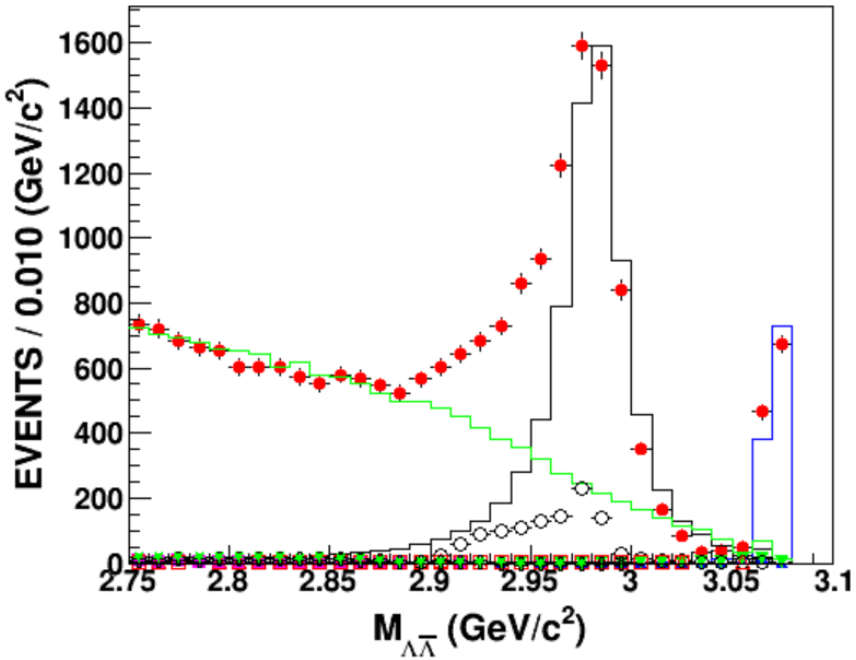
main contribution from

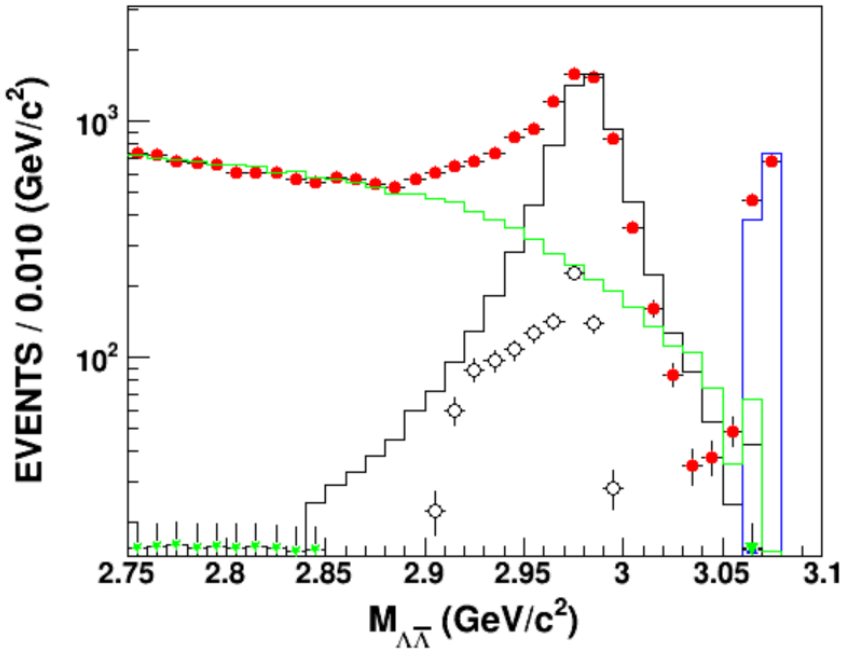
$$J/\psi \rightarrow \begin{cases} \Lambda\bar{\Lambda} \\ \Sigma_0(\gamma\Lambda)\bar{\Sigma}_0(\gamma\bar{\Lambda}) \end{cases}$$

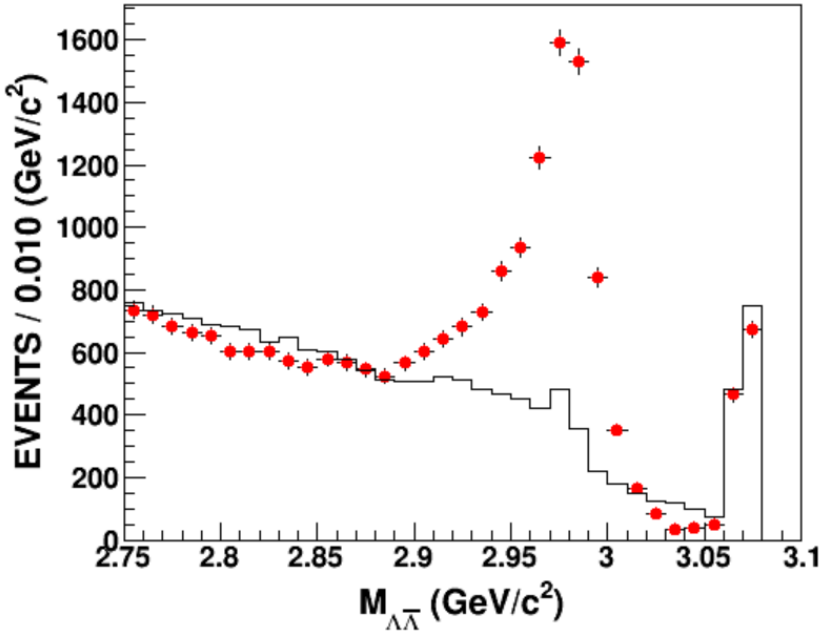




Background study







1.Red dot: data

2.Black hist.: $\eta_c \to \Lambda\bar{\Lambda}$

3.Blue Hsit. : $J/\psi \to \Lambda\bar{\Lambda}$

4.Green Hist. : $J/\psi \to \gamma\Lambda\bar{\Lambda}$

5.Purple Squre: $J/\psi \to \pi^0\Lambda\bar{\Lambda}$

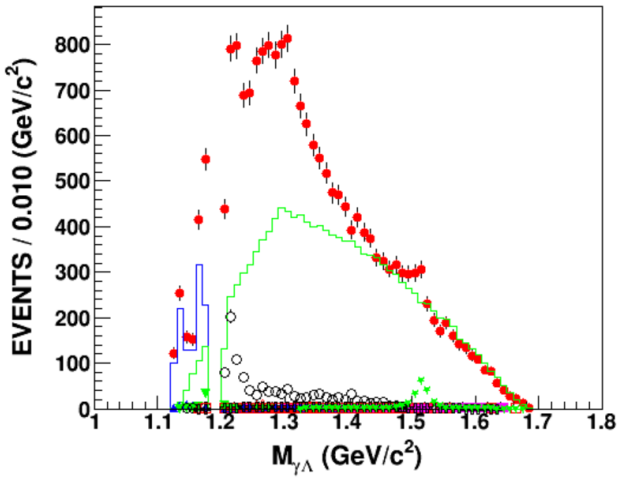
6.Blue Triangle: $J/\psi \to \bar{\Sigma}^0\Lambda$

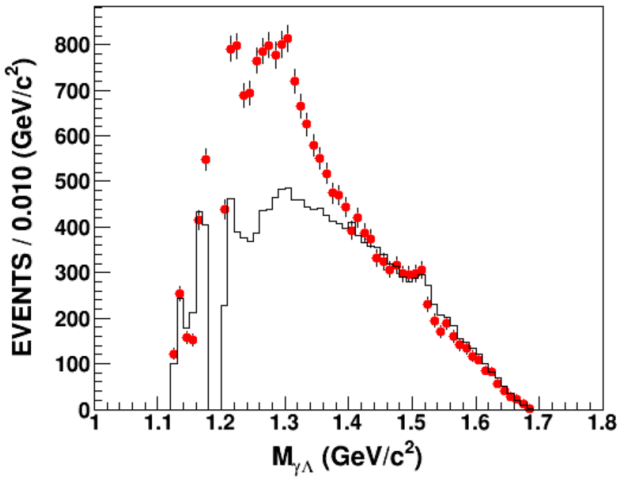
7.Green Anti-triangle: $J/\psi \to \Sigma^0\bar{\Lambda}$

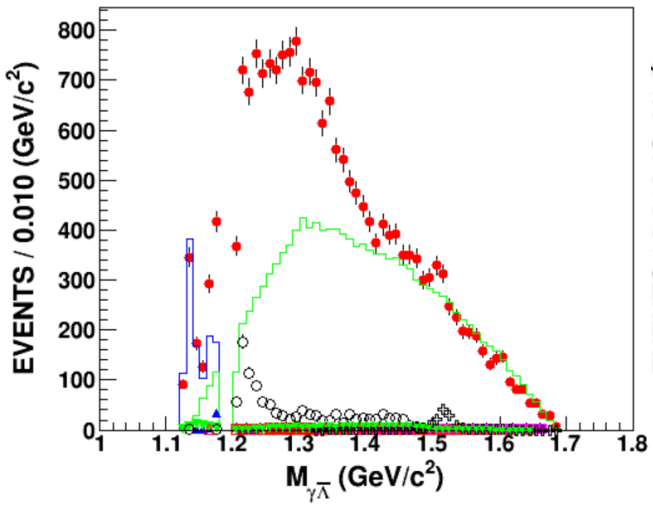
8.Black Circle: $J/\psi \to \bar{\Sigma}^0\Sigma^0$

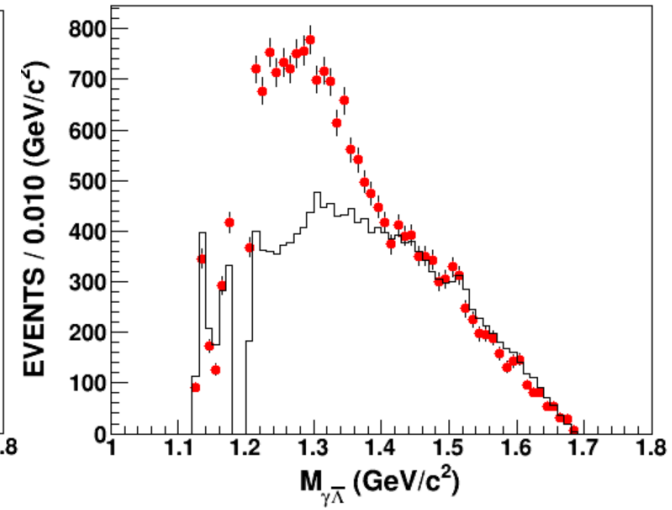
9.Green star: $J/\psi \to \Lambda(1520)\,\bar{\Lambda}$+c.c

Background study









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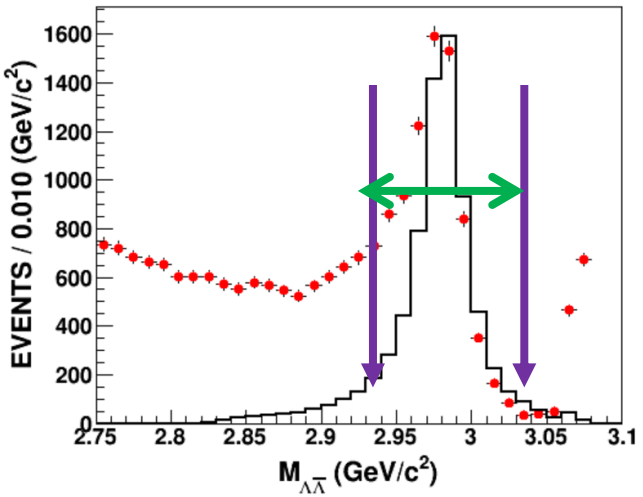
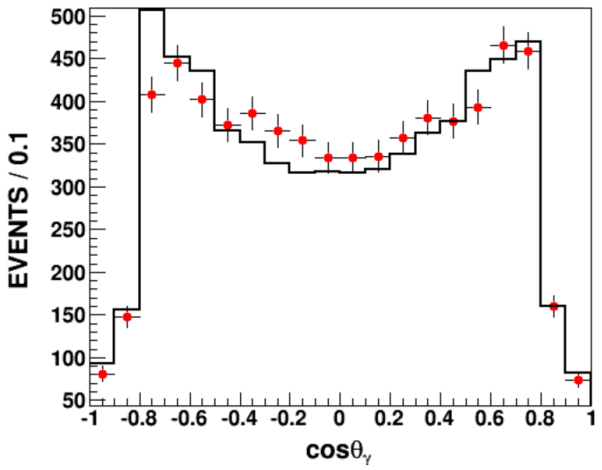
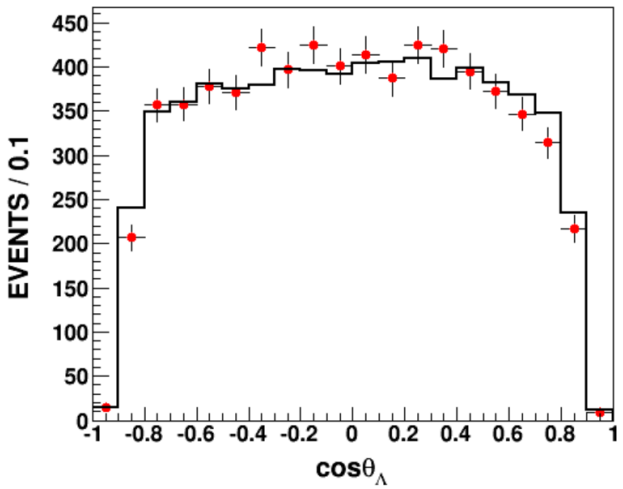
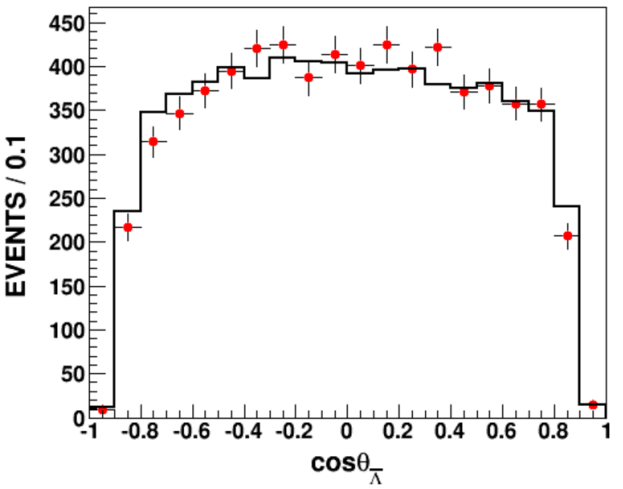
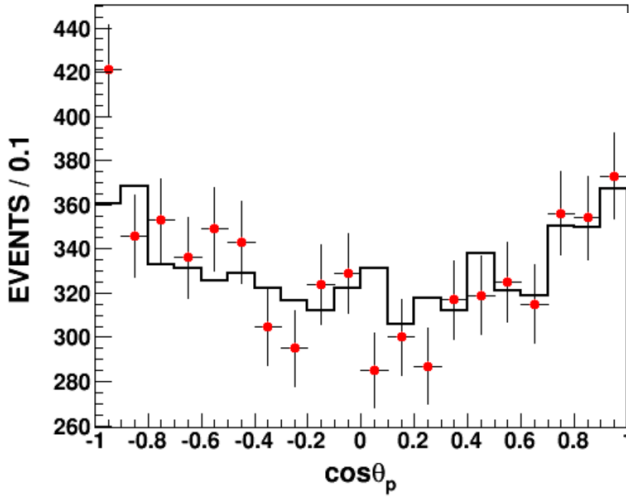
Helicity angular distribution

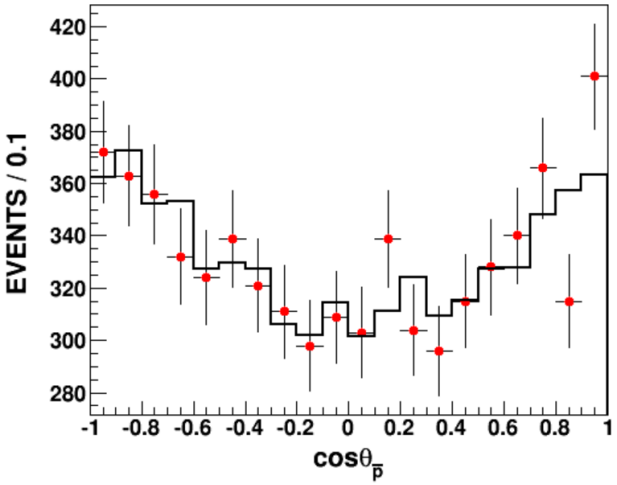


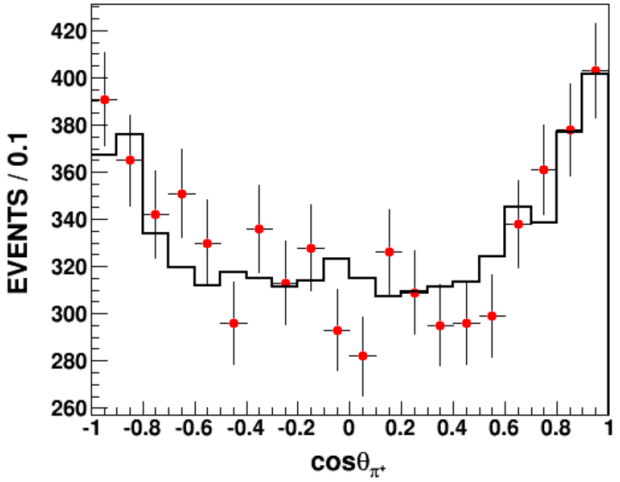


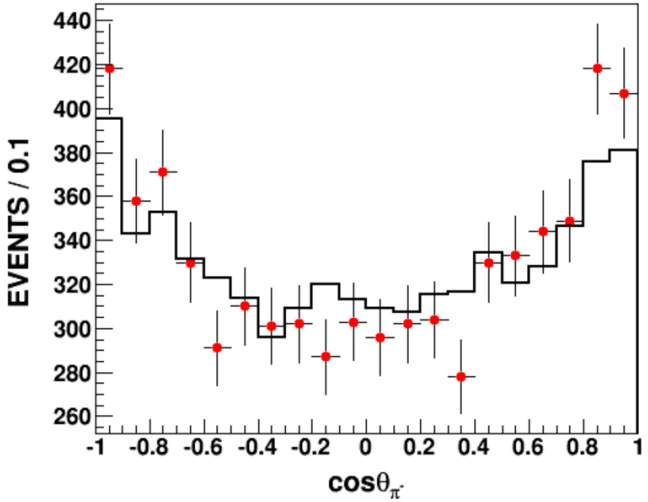












Summary

- Preliminary study of $\eta_c \to \Lambda\bar{\Lambda}$

  1) Selection Optimization: final efficiency is 12.13%.

  2) Background study:

  main contribution from $J/\psi \to \Lambda\bar{\Lambda}$, $\gamma\Lambda\bar{\Lambda}$ (including the resonance, such as $\Lambda(1520)$, Σ^0 and so on) and $\pi^0\Lambda\bar{\Lambda}$.

  3) Helicity angular distribution: MC and data are consistent to each other within η_c mass window.

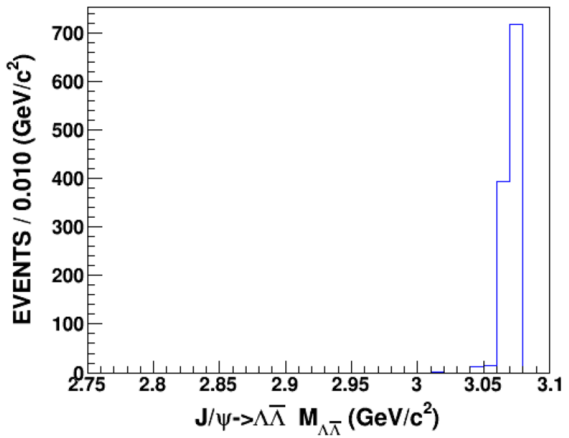
- Next work:

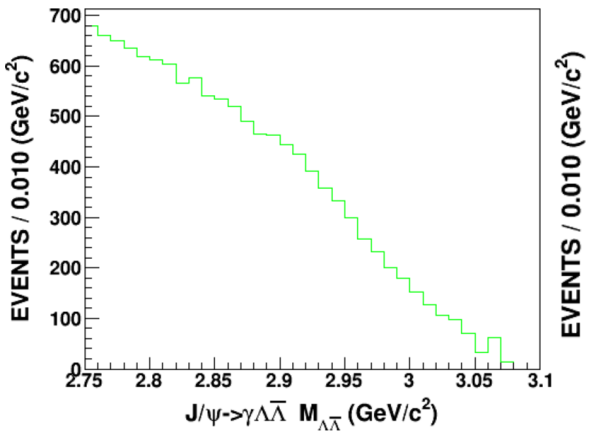
  1) Fixed the selection

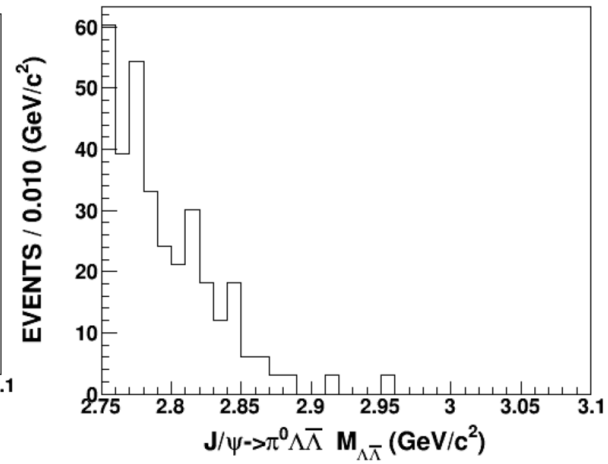
  2) Fitting the mass spectrum of $\Lambda\bar{\Lambda}$

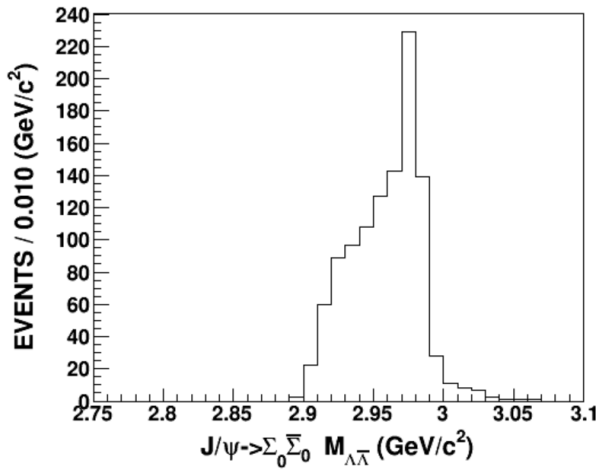
Back up

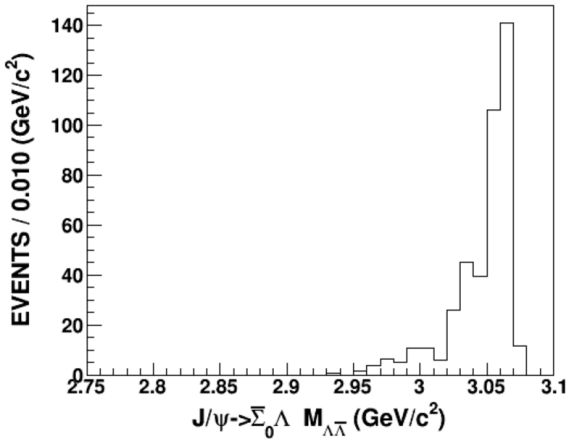
Back up

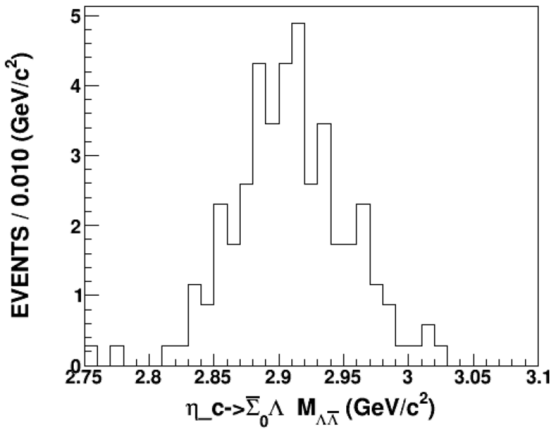

EVENTS / 0.010 (GeV/c²)
J/ψ->ΛΛ̄ M_ΛΛ̄ (GeV/c²)


EVENTS / 0.010 (GeV/c²)
J/ψ->γΛΛ̄ M_ΛΛ̄ (GeV/c²)


EVENTS / 0.010 (GeV/c²)
J/ψ->π⁰ΛΛ̄ M_ΛΛ̄ (GeV/c²)


EVENTS / 0.010 (GeV/c²)
J/ψ->Σ₀Σ̄₀ M_ΛΛ̄ (GeV/c²)


EVENTS / 0.010 (GeV/c²)
J/ψ->Σ̄₀Λ M_ΛΛ̄ (GeV/c²)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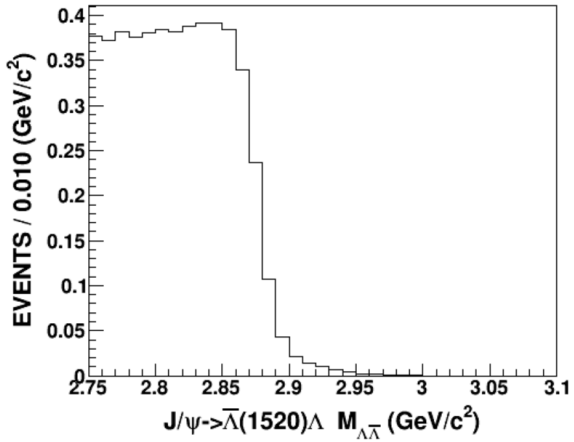
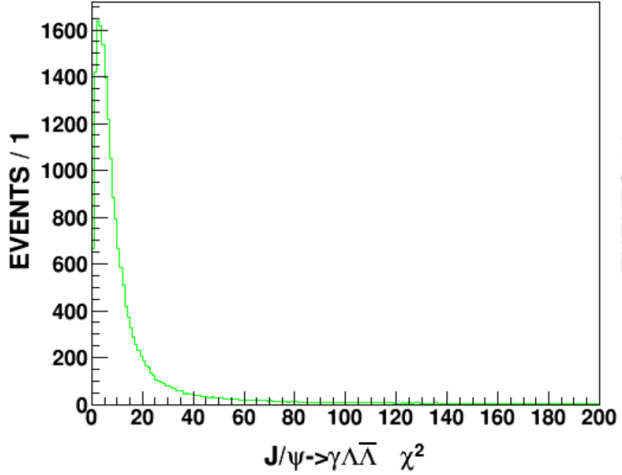
η_c->Σ̄₀Λ M_ΛΛ̄ (GeV/c²)


EVENTS / 0.010 (GeV/c²)
J/ψ->Λ̄(1520)Λ M_ΛΛ̄ (GeV/c²)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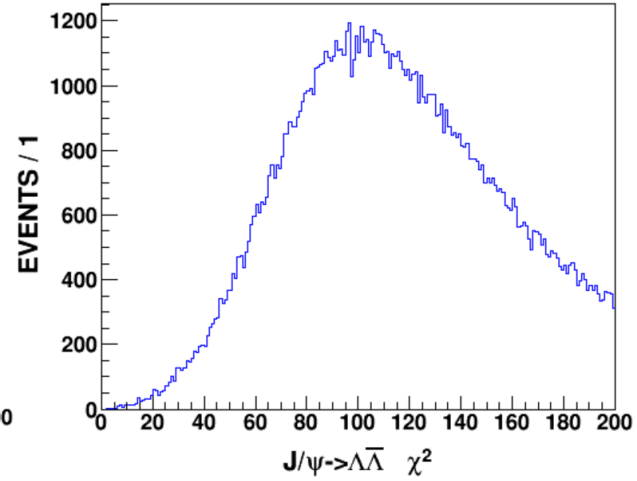
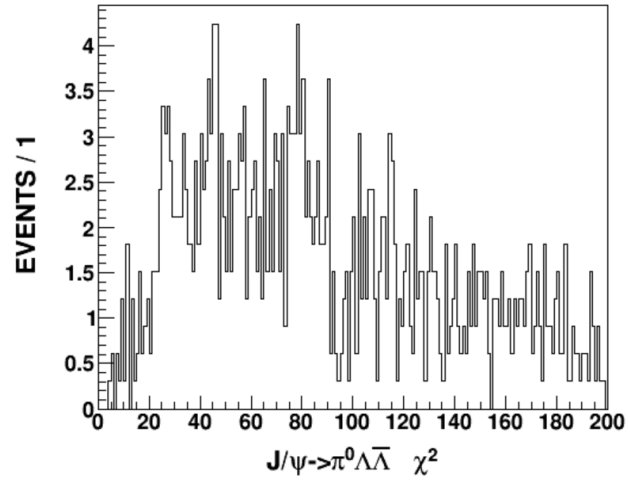
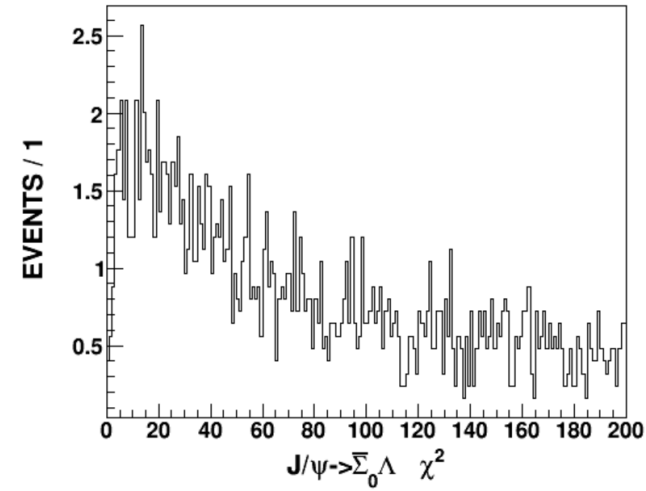
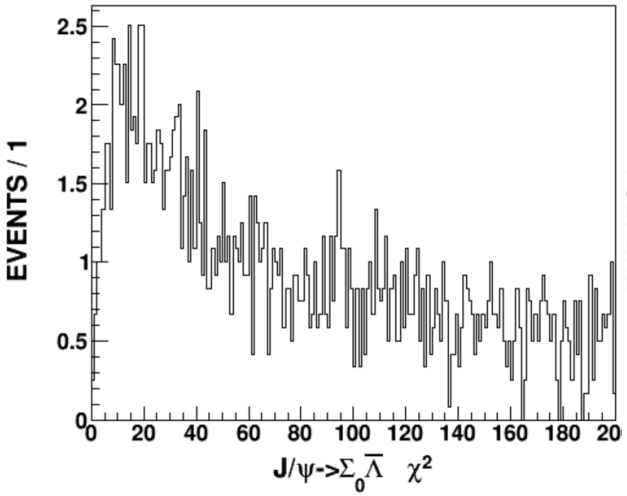
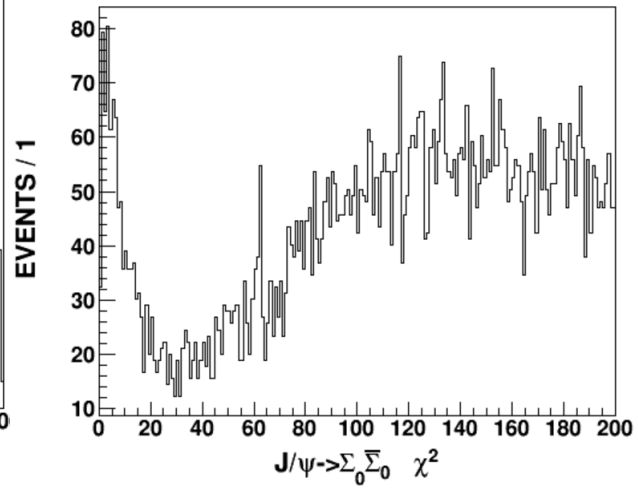
J/ψ->γΛΛ̄ χ²


EVENTS / 1
J/ψ->ΛΛ̄ χ²


EVENTS / 1
J/ψ->π⁰ΛΛ̄ χ²


EVENTS / 1
J/ψ->Σ̄₀Λ χ²


EVENTS / 1
J/ψ->Σ₀Λ̄ χ²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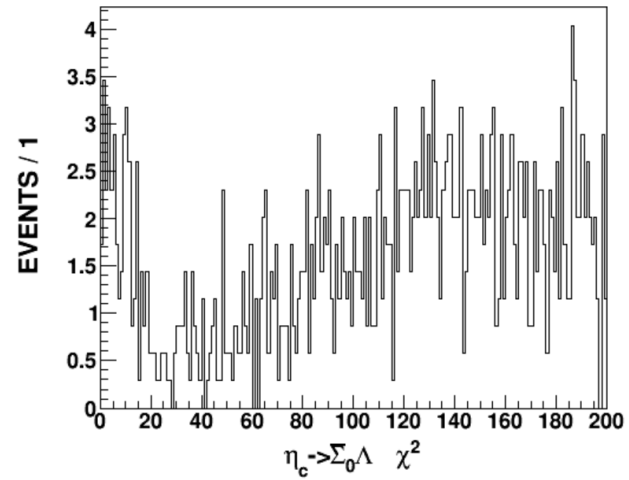
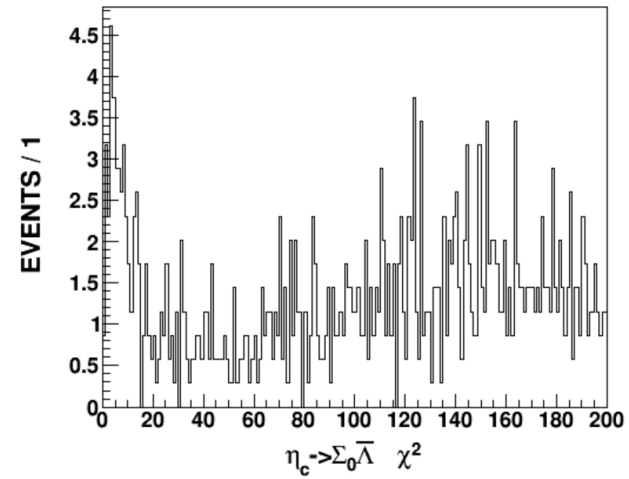
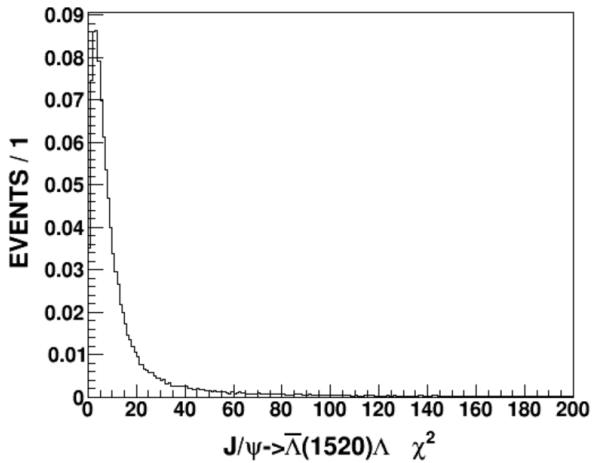
J/ψ->Σ₀Σ̄₀ χ²


EVENTS / 1
ηc->Σ₀Λ χ²


EVENTS / 1
ηc->Σ₀Λ̄ χ²


EVENTS / 1
J/ψ->Λ̄(1520)Λ χ²