

*Probe the Form Factors in decay  $J/\psi \rightarrow \Sigma^0 \bar{\Sigma}^0$*

Xinxin Ma, Haibo Li

Institute of High Energy Physics  
maxx@ihep.ac.cn

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# Outline

- 1 *Motivation*
- 2 *Event Selection*
- 3 *Background*
- 4 *Signal Yield*
- 5 *Summary*

# Motivation

## A) Understand the structure of hadron

- ✓ Direct way: electron hadron scattering

$$e^- B \rightarrow e^- B$$

- ✓ **BESIII**: form factors and transition form factors

$$e^+ e^- \rightarrow B \bar{B} \text{ or } B' \rightarrow e^+ e^- B$$

## B) Measure the form factors of Hyperons

$$\langle B \bar{B} | j_{em}^\mu | \rangle = e \bar{u}_B \left( \gamma^\mu F_1(q^2) - \frac{i \sigma^{\mu\nu} q_\nu}{2m_B} F_2(q^2) \right) \nu_B \quad (1)$$

And the famous known form factors is

$$G_M = F_1 + F_2, \quad G_E = F_1 + \frac{q^2}{4m} F_2 \quad (2)$$

What should be measured is  $|\frac{G_E}{G_M}|$  and  $\Phi$ :

$$G_E = \text{Re}^{i\Phi} G_M \quad (3)$$

# Event Selection

## A) Good charged track

- ✓ Vertex:  $V_z < 20 \text{ cm}$
- ✓ Polar angle:  $\cos\theta < 0.93$

## B) Photons Candidates

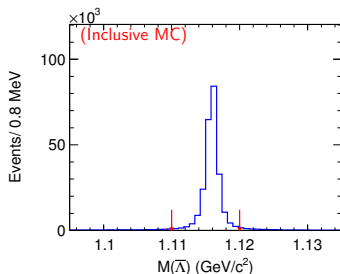
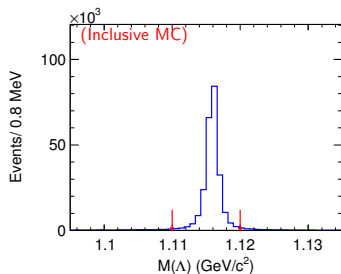
- ✓ Barrel:  $\cos\theta < 0.8, E_\gamma > 25 \text{ MeV}$
- ✓ End Cap:  $0.86 < \cos\theta < 0.92, E_\gamma > 50 \text{ MeV}$

## C) Proton candidates:

- ✓  $\text{prob}(P) > 0, \text{prob}(P) > \text{prob}(\pi), \text{prob}(P) > \text{prob}(K)$

# $\Lambda$ Selection

- ✓  $\Lambda$  Candidates:
  - ✓ Mass: [1.110, 1.120]  $\text{GeV}/c^2$
  - ✓ Primary Vertex Fit:  $\chi^2 < 200$

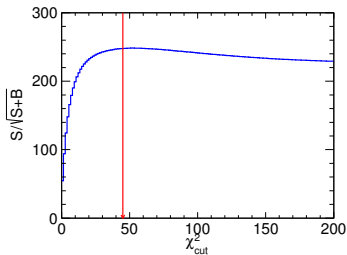
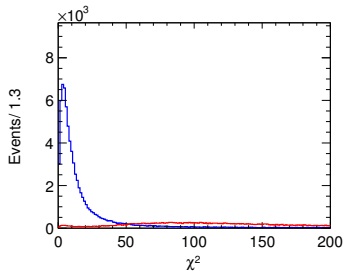


# Background

No.	decay chain	final states	iTopology	nEvt	nTot
0	$J/\psi \rightarrow \Sigma^0 \bar{\Sigma}^0, \Sigma^0 \rightarrow \Lambda \gamma, \bar{\Sigma}^0 \rightarrow \gamma \bar{\Lambda}, \Lambda \rightarrow p \pi^-, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^+ \gamma \gamma p$	0	87618	87618
1	$J/\psi \rightarrow \Lambda \bar{\Sigma}^0, \Lambda \rightarrow p \pi^-, \bar{\Sigma}^0 \rightarrow \gamma \bar{\Lambda}, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^+ \gamma p$	3	3082	90700
2	$J/\psi \rightarrow \Sigma^{*0} \bar{\Lambda}, \Sigma^{*0} \rightarrow \Lambda \pi^0, \bar{\Lambda} \rightarrow \pi^+ \bar{p}, \Lambda \rightarrow p \pi^-$	$\pi^- \bar{p} \pi^0 \pi^+ p$	4	2815	93515
3	$J/\psi \rightarrow \Lambda \bar{\Sigma}^{*0}, \Lambda \rightarrow p \pi^-, \bar{\Sigma}^{*0} \rightarrow \pi^0 \bar{\Lambda}, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^0 \pi^+ p$	5	2803	96318
4	$J/\psi \rightarrow \Sigma^0 \bar{\Lambda}, \Sigma^0 \rightarrow \Lambda \gamma, \bar{\Lambda} \rightarrow \pi^+ \bar{p}, \Lambda \rightarrow p \pi^-$	$\pi^- \bar{p} \pi^+ \gamma p$	8	2268	98586
5	$J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \Sigma^0 \bar{\Lambda}, \Sigma^0 \rightarrow \Lambda \gamma, \bar{\Lambda} \rightarrow \pi^+ \bar{p}, \Lambda \rightarrow p \pi^-$	$\pi^- \bar{p} \pi^+ \gamma \gamma p$	9	1572	100158
6	$J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \Lambda \bar{\Sigma}^0, \Lambda \rightarrow p \pi^-, \bar{\Sigma}^0 \rightarrow \gamma \bar{\Lambda}, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^+ \gamma \gamma p$	1	1469	101627
7	$J/\psi \rightarrow \Lambda \gamma \bar{\Sigma}^0, \Lambda \rightarrow p \pi^-, \bar{\Sigma}^0 \rightarrow \gamma \bar{\Lambda}, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^+ \gamma \gamma p$	6	994	102621
8	$J/\psi \rightarrow \Sigma^0 \gamma \bar{\Lambda}, \Sigma^0 \rightarrow \Lambda \gamma, \bar{\Lambda} \rightarrow \pi^+ \bar{p}, \Lambda \rightarrow p \pi^-$	$\pi^- \bar{p} \pi^+ \gamma \gamma p$	7	944	103565
9	$J/\psi \rightarrow \Lambda \gamma \bar{\Lambda}, \Lambda \rightarrow p \pi^-, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^+ \gamma p$	13	516	104081
10	$J/\psi \rightarrow \Sigma^+ \bar{\Sigma}^{*-}, \Sigma^+ \rightarrow p \pi^0, \bar{\Sigma}^{*-} \rightarrow \pi^- \bar{\Lambda}, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^0 \pi^+ p$	16	191	104272
11	$J/\psi \rightarrow \Lambda \pi^0 \bar{\Lambda}, \Lambda \rightarrow p \pi^-, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^0 \pi^+ p$	2	188	104460
12	$J/\psi \rightarrow \Sigma^{*+} \bar{\Sigma}^-, \Sigma^{*+} \rightarrow \Lambda \pi^+, \bar{\Sigma}^- \rightarrow \pi^0 \bar{p}, \Lambda \rightarrow p \pi^-$	$\pi^- \bar{p} \pi^0 \pi^+ p$	12	98	104558
13	$J/\psi \rightarrow \Lambda \pi^+ \bar{\Sigma}^-, \Lambda \rightarrow p \pi^-, \bar{\Sigma}^- \rightarrow \pi^0 \bar{p}$	$\pi^- \bar{p} \pi^0 \pi^+ p$	19	93	104651
14	$J/\psi \rightarrow \Sigma^+ \pi^- \bar{\Lambda}, \Sigma^+ \rightarrow p \pi^0, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^0 \pi^+ p$	10	78	104729
15	$J/\psi \rightarrow \Sigma^{*0} \bar{\Sigma}^0, \Sigma^{*0} \rightarrow \Lambda \pi^0, \bar{\Sigma}^0 \rightarrow \gamma \bar{\Lambda}, \Lambda \rightarrow p \pi^-, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^0 \pi^+ \gamma p$	14	74	104803
16	$J/\psi \rightarrow \Sigma^0 \bar{\Sigma}^{*0}, \Sigma^0 \rightarrow \Lambda \gamma, \bar{\Sigma}^{*0} \rightarrow \pi^0 \bar{\Lambda}, \Lambda \rightarrow p \pi^-, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^0 \pi^+ \gamma p$	15	72	104875
17	$J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \Sigma^0 \bar{\Sigma}^0, \Sigma^0 \rightarrow \Lambda \gamma, \bar{\Sigma}^0 \rightarrow \gamma \bar{\Lambda}, \Lambda \rightarrow p \pi^-, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^+ \gamma \gamma \gamma p$	11	67	104942
18	$J/\psi \rightarrow \Sigma^0 \gamma \bar{\Sigma}^0, \Sigma^0 \rightarrow \Lambda \gamma, \bar{\Sigma}^0 \rightarrow \gamma \bar{\Lambda}, \Lambda \rightarrow p \pi^-, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^+ \gamma \gamma \gamma p$	20	58	105000
19	$J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \Lambda \bar{\Lambda}, \Lambda \rightarrow p \pi^-, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^+ \gamma p$	17	28	105028
20	$J/\psi \rightarrow \Lambda \bar{\Sigma}^{*0}, \Lambda \rightarrow p \pi^-, \bar{\Sigma}^{*0} \rightarrow \pi^+ \bar{\Sigma}^-, \bar{\Sigma}^- \rightarrow \pi^0 \bar{p}$	$\pi^- \bar{p} \pi^0 \pi^+ p$	21	26	105054
21	$J/\psi \rightarrow \Sigma^{*0} \bar{\Lambda}, \Sigma^{*0} \rightarrow \Sigma^+ \pi^-, \bar{\Lambda} \rightarrow \pi^+ \bar{p}, \Sigma^+ \rightarrow p \pi^0$	$\pi^- \bar{p} \pi^0 \pi^+ p$	18	25	105079
22	$J/\psi \rightarrow p \eta \bar{p}, \eta \rightarrow \pi^+ \pi^0 \pi^-$	$\pi^- \bar{p} \pi^0 \pi^+ p$	24	17	105096
23	$J/\psi \rightarrow p \pi^+ \pi^0 \pi^- \bar{p}$	$\pi^- \bar{p} \pi^0 \pi^+ p$	27	13	105109
24	$J/\psi \rightarrow \Lambda \bar{\Lambda}, \Lambda \rightarrow p \pi^-, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^+ p$	23	11	105120
25	$J/\psi \rightarrow \Sigma^0 \bar{\Sigma}^0, \Sigma^0 \rightarrow \Lambda \gamma, \bar{\Sigma}^0 \rightarrow \gamma \bar{\Lambda}, \Lambda \rightarrow p \gamma_{FSR} \pi^-, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$	$\pi^- \bar{p} \pi^+ \gamma \gamma p$	26	8	105128
26	$J/\psi \rightarrow \Sigma^0 \bar{\Sigma}^0, \Sigma^0 \rightarrow \Lambda \gamma, \bar{\Sigma}^0 \rightarrow \gamma \bar{\Lambda}, \Lambda \rightarrow p \pi^-, \bar{\Lambda} \rightarrow \pi^+ \gamma_{FSR} \bar{p}$	$\pi^- \bar{p} \pi^+ \gamma \gamma p$	22	8	105136

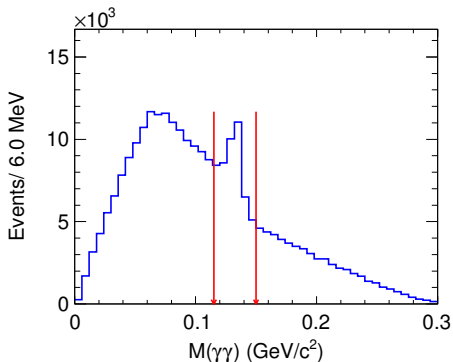
# Require on $\chi_{4C}^2$

✓ Optimization:  $\chi^2 < 45$



# Veto $\pi^0$

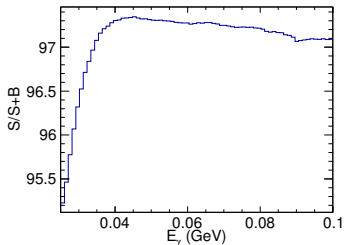
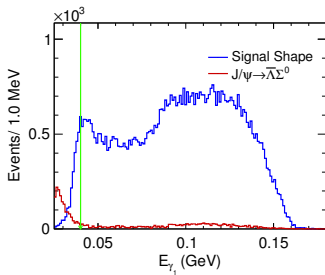
- ✓  $M(\gamma\gamma) < 0.115$  or  $M(\gamma\gamma) > 0.150$
- ✓ Suppress background:  $J/\psi \rightarrow \bar{\Lambda}\Sigma^*, \Sigma^* \rightarrow \Sigma^0\pi^0$





# Suppress Fake $\gamma$

- ✓ Fake  $\gamma$  from Barrel-Cap :  $E_\gamma$  less than 50 MeV
- ✓ Require the energy, of both  $\gamma$ , larger than 40 MeV



## A) Method

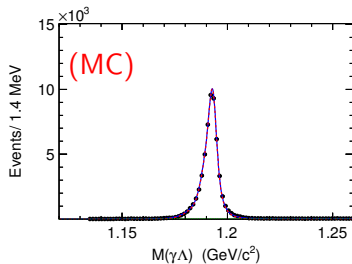
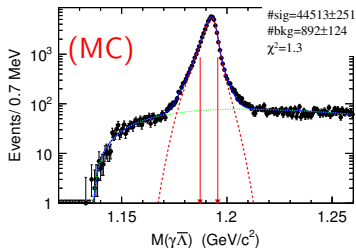
- ✓ Divide the  $M(\Sigma^0)$  spectrum into signal region ( **S** ) and sideband region ( **B** )
- ✓ Fit to  $M(\bar{\Sigma}^0)$  spectrum, obtaining the yields  $n_{S,B}$  for region S and B.
- ✓ Signal Yield:  $n_S - c \cdot n_B$

## B) Model:

- ✓ Signal: MC shape  $\otimes$  Gaus
- ✓ Flat Background: **Argus**

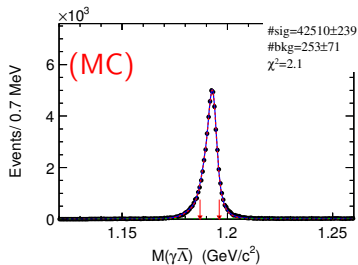
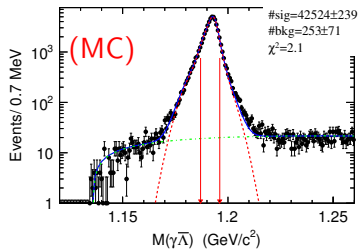
# Signal region and Side Band

- ✓ Side Band: [1.22, 1.26] GeV



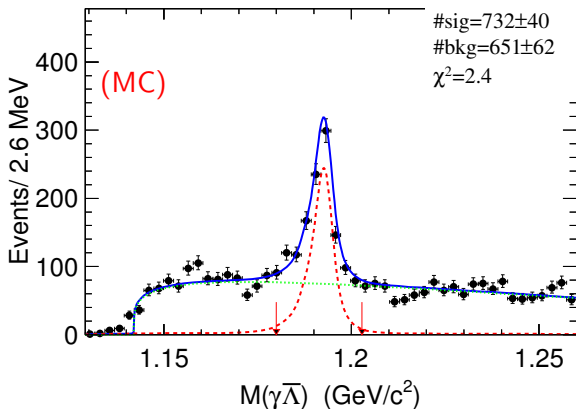
# $\bar{\Sigma}^0$ Yields (1)

- ✓ Fit to  $M(\bar{\Sigma}^0)$  in  $\Sigma^0$  signal region



# $\bar{\Sigma}^0$ Yields (2)

- ✓ Fit to  $M(\bar{\Sigma}^0)$  in  $\Sigma^0$  side band



# Summary

A) Main background:

$$J/\psi \rightarrow \Sigma^0 \bar{\Lambda} + c.c$$

$$J/\psi \rightarrow \gamma \Sigma^0 \bar{\Lambda} + c.c$$

$$J/\psi \rightarrow \gamma \eta_c, \eta_c \rightarrow \Sigma^0 \bar{\Lambda} + c.c$$

B) The background level is about 3%