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

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Outline

Motivation

A) Understand the structure of hadron

- ✓ Direct way: electron hadron scattering

$$e^- B \to e^- B$$

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

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

B) Measure the form factors of Hyperons

$$< B\bar{B}|j^{\mu}_{em}| >= e\bar{u}_B \left(\gamma^{\mu} F_1(q^2) - \frac{i\sigma^{\mu\nu} q_{\nu}}{2m_B} F_2(q^2)\right) \nu_B \tag{1}$$

And the famous known form factors is

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

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

$$G_E = Re^{i\Phi} G_M \tag{3}$$

Event Selection

A) Good charged track

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

B) Photons Candidates

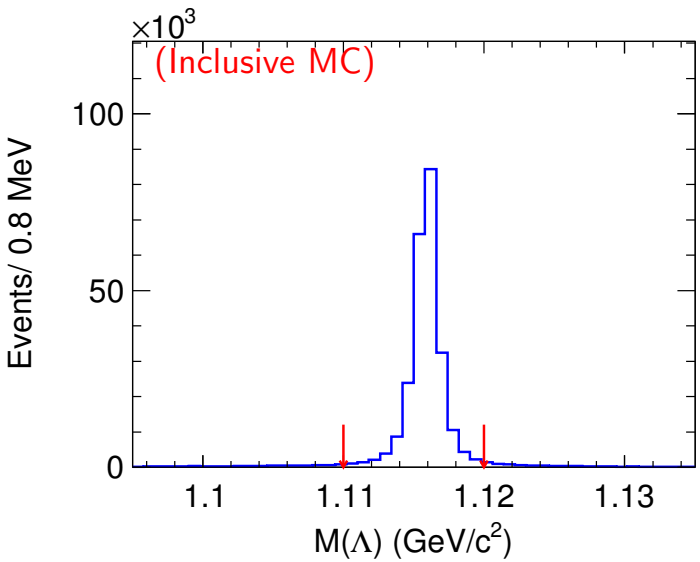
- ✓ Barrel: $cos\theta < 0.8$, $E_\gamma > 25$ MeV
- ✓ End Cap: $0.86 < cos\theta < 0.92$, $E_\gamma > 50$ MeV

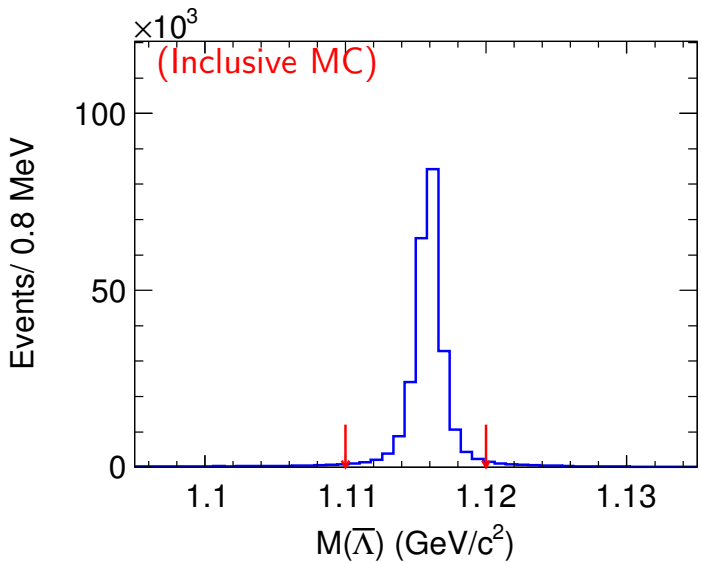
C) Proton candidates:

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

Λ *Selection*

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



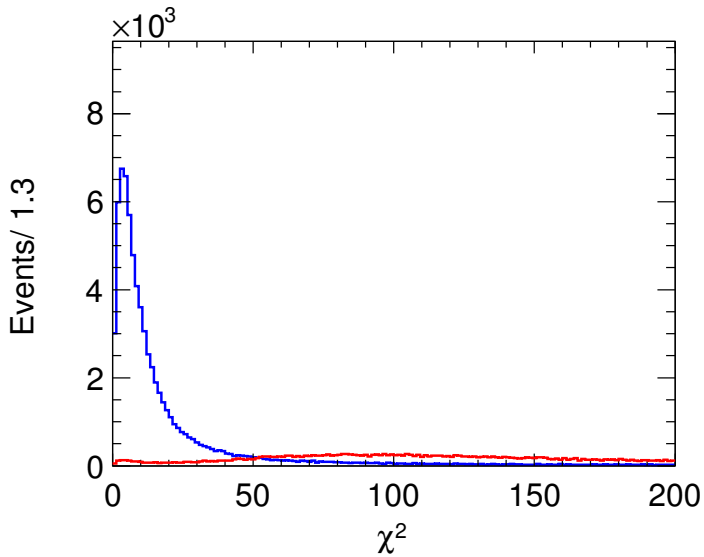


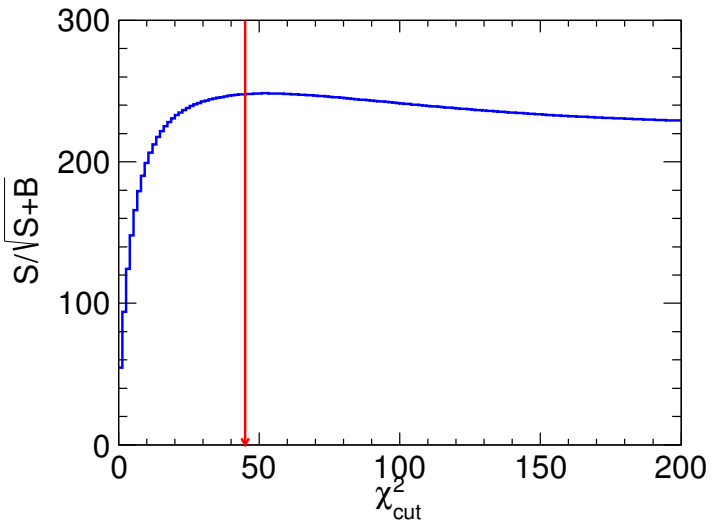
Background

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

Require on χ^2_{4C}

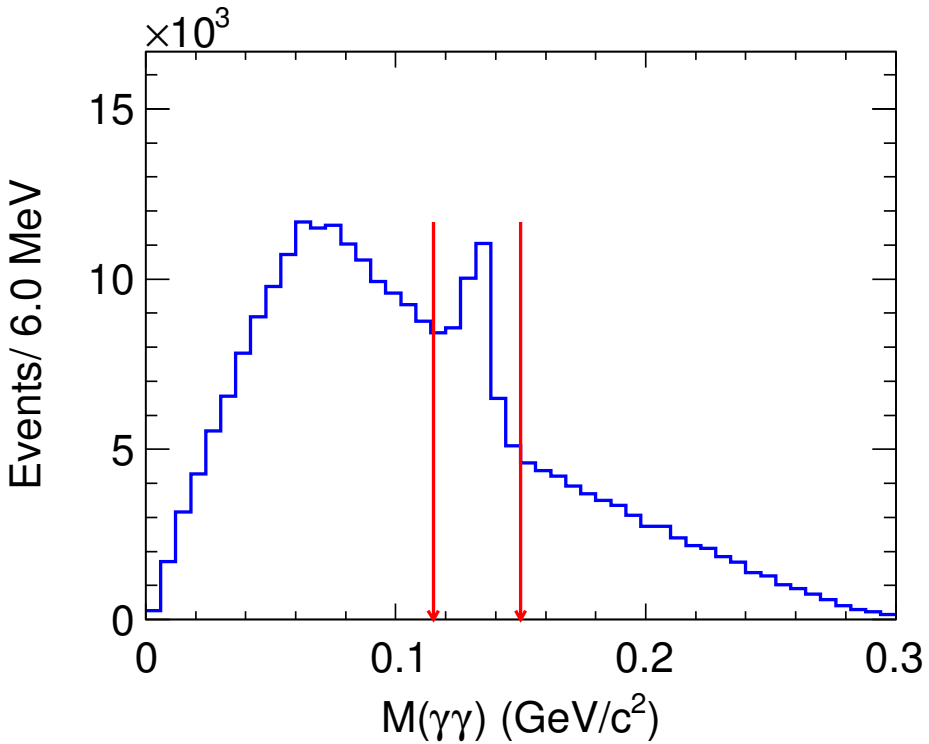
✓ Optimization: $\chi^2 < 45$





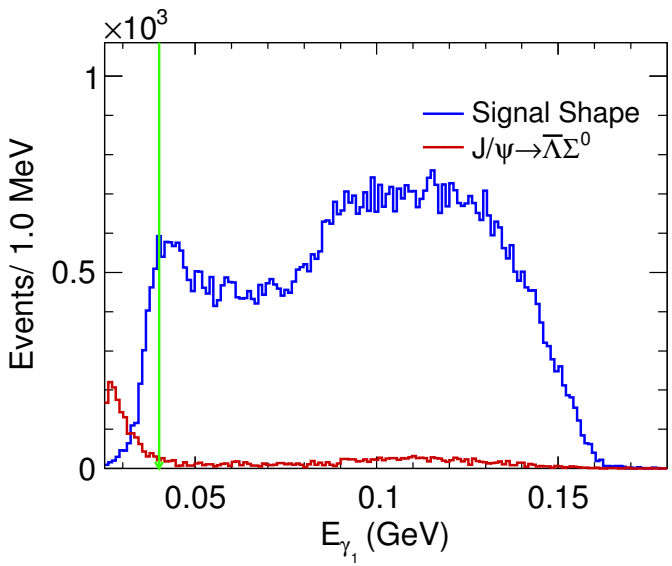
Veto π^0

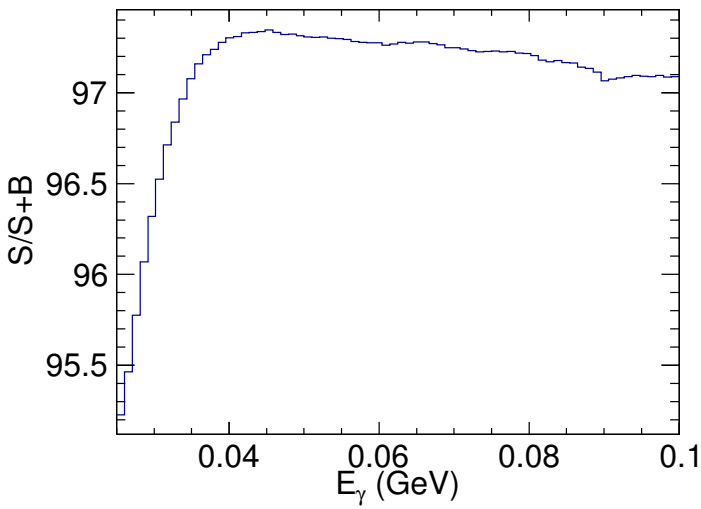
- ✓ $M(\gamma\gamma) < 0.115$ or $M(\gamma\gamma) > 0.150$
- ✓ Suppress background: $J/\psi \to \bar{\Lambda}\Sigma^*, \Sigma^* \to \Sigma^0\pi^0$



Suppress Fake γ

- ✓ Fake γ from Barrel-Cap :E_γ less than 50 MeV
- ✓ Require the energy, of both γ, larger than 40 MeV





Fit Procedure

A) Method

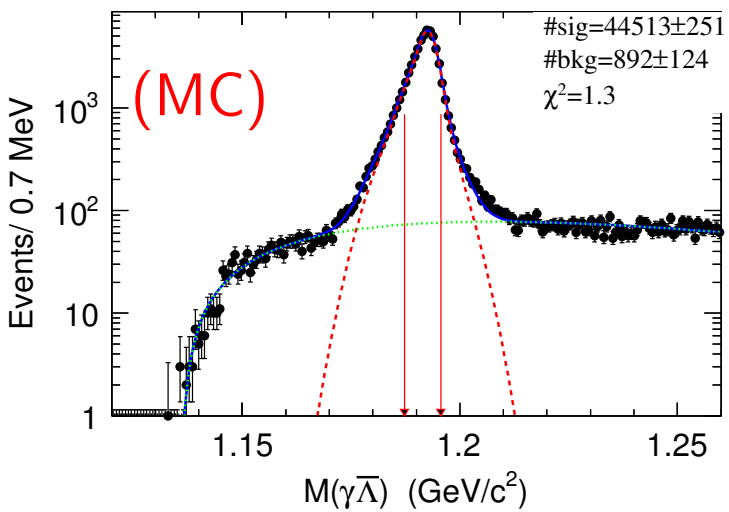
- ✓ Divide the $M(\Sigma^0)$ spectrum into signal region (**S**) and sideband region (**B**)
- ✓ Fit to $M(\bar{\Sigma}^0)$ spectrum, obtaining the yields $n_{S,B}$ for region S and B.
- ✓ Signal Yield: $n_S - c \cdot n_B$

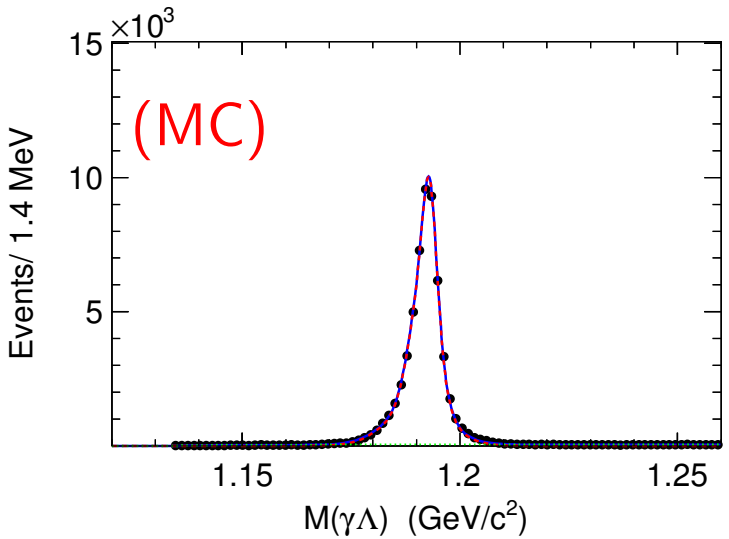
B) Model:

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

Signal region and Side Band

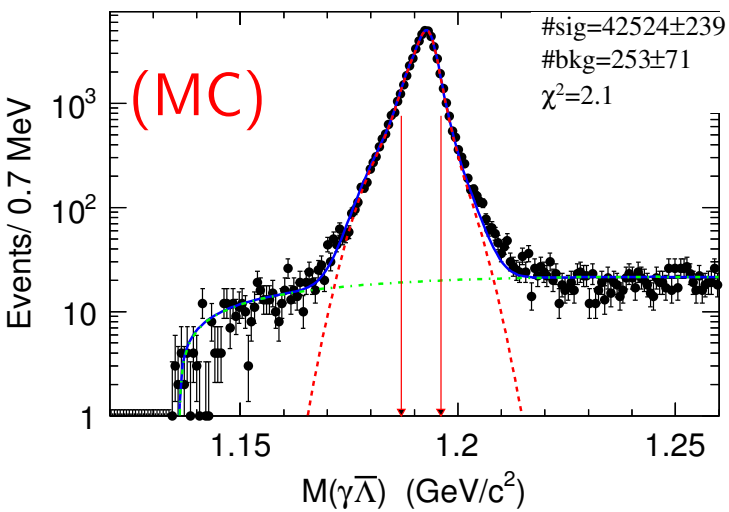
✓ Side Band: $[1.22, 1.26]$ GeV

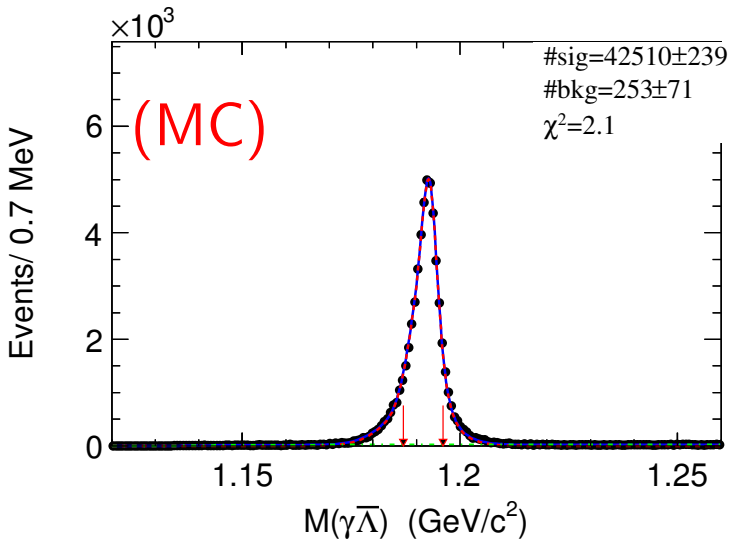




$\bar{\Sigma}^0$ *Yields (1)*

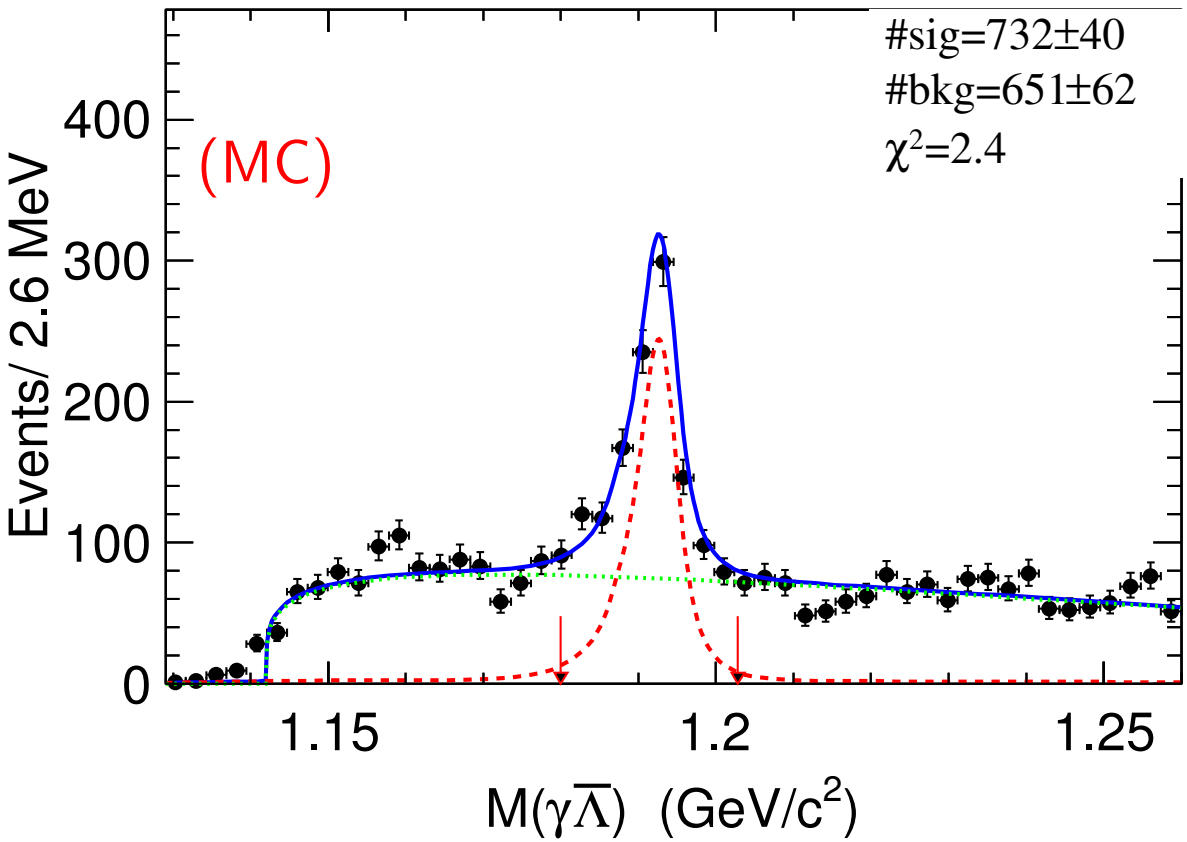
✓ Fit to $M(\bar{\Sigma}^0)$ in Σ^0 signal region





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

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



Summary

A) Main background:

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

B) The background level is about 3%

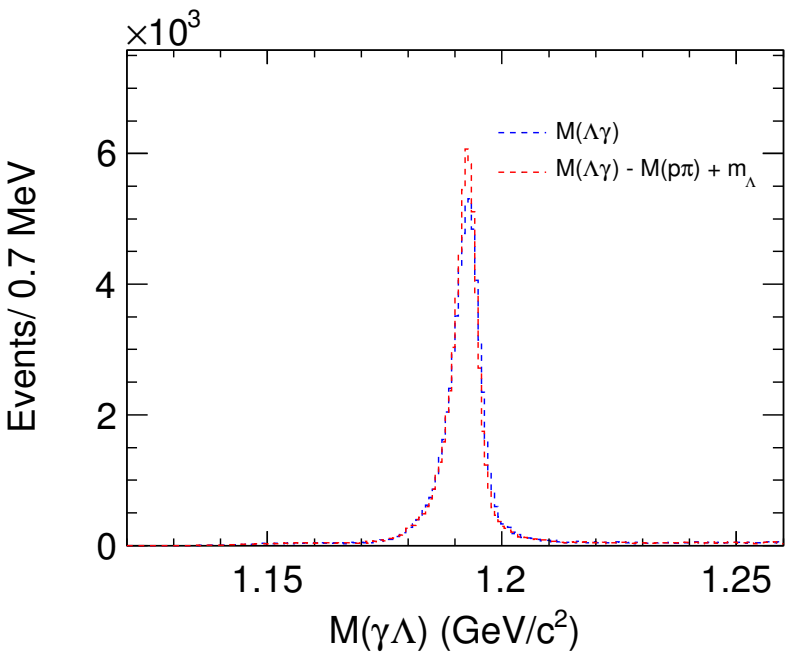
Update

Best Candidates

- ✓ The mass of Σ^0:

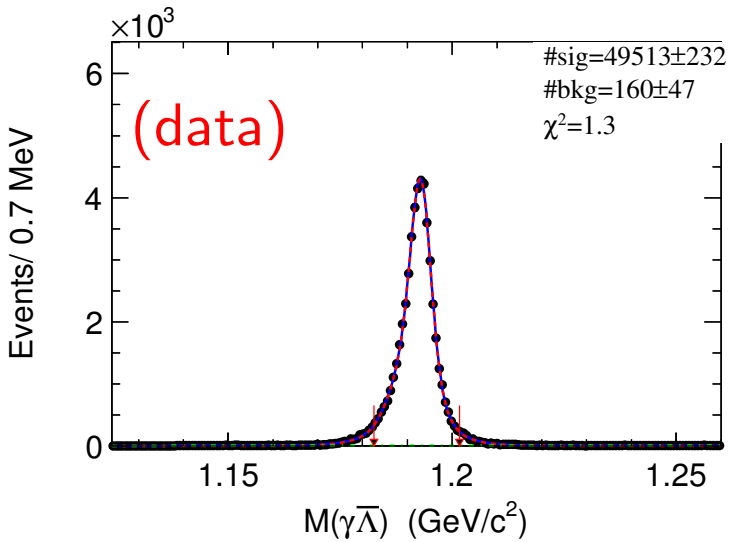
$$M(\Sigma^0) = M(\Lambda\gamma) - M(p\pi) - m_\Lambda$$

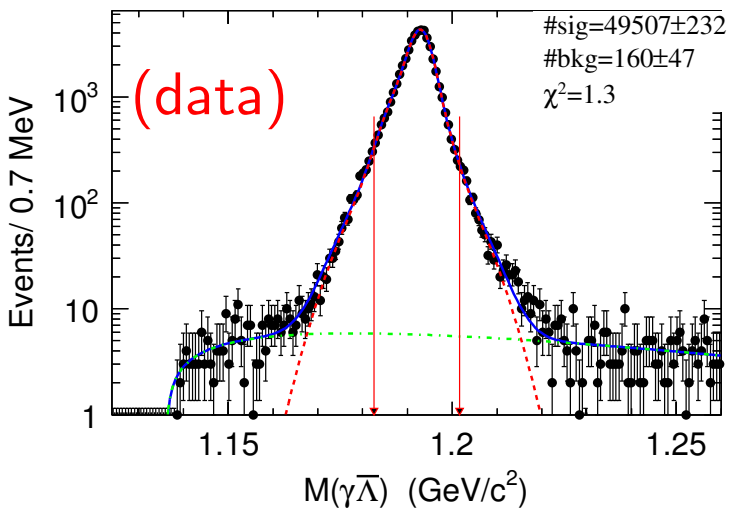
- ✓ The resolution is improved, and use $(M(\bar{\Sigma}) - m_{\bar{\Sigma}})^2 + (M(\Sigma) - m_{\bar{\Sigma}})^2 = min$ to select the best combine candidate.



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

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





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

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