Search for Σ^0 *Dalitz Decay*

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Outline

Motivation

A) The $\mathcal{B}(\Sigma \rightarrow \Lambda e^{+} e^{-})$ is predicted to be 0.00545 by G. Feinberg at 1958. (PhysRev.109.1019)

B) H. Courant first discovered the dalitz decay, and determined the parity of Σ^0. (PRL.10.409)

C) The BF is not measured to date.

Method

A) Search signal in channel:

$$J/\psi \rightarrow \Sigma^0 \bar{\Sigma}^0$$

B) One Σ decay into $\gamma\Lambda$

C) Search for signal in the remaining tracks.

$$\Sigma \rightarrow \Lambda e^+ e^-, \gamma\Lambda$$

D) Obtain the relative branching fraction:

$$\frac{\Gamma(\Sigma \rightarrow e^+ e^- \Lambda)}{\Gamma(\Sigma \rightarrow \gamma\Lambda)} \tag{1}$$

Σ^0 *Sample*

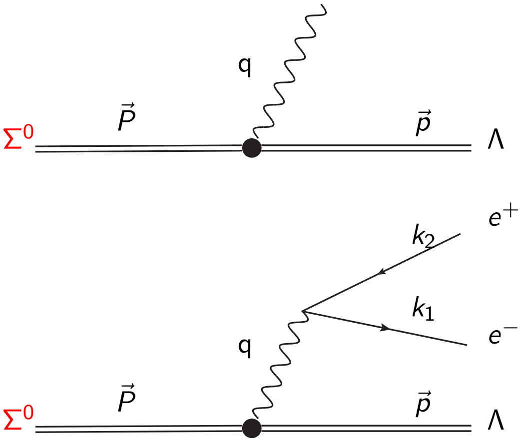
- ✓ DataSet: all J/ψ sample collected during 2009 to 2012 years.
- ✓ $J/\psi \to \Sigma^0\bar{\Sigma}^0$

$$\frac{d\ \sigma}{d\ \theta} \sim 1 + \alpha \cos\theta \qquad (2)$$

- ✓ The α is measured to be 0.65 ± 0.11
  BESII:PLB 632, 181(2006)
- ✓ Branching fraction

$$\mathcal{B} = (1.171 \pm 0.031) \times 10^{-3} \qquad (3)$$

Amplitude I



$\Sigma^0 \longrightarrow \Lambda e^+ e^-$

Amplitude II

A) $\Sigma - \Lambda$ vertex

$$\Gamma_\mu = e\left[\left(\gamma_\mu \frac{q^2}{M^2} - \frac{\Delta}{M^2} q_\mu\right) F_1 + i\sigma_{\mu\nu}\frac{q_\nu}{M} F_2\right] \quad (4)$$

- ✓ Assume: $F_1 \in \mathbb{R}$, $F_2 \in \mathbb{Z}$
- ✓ Usually $|F_2| << |F_1|$

B) Hadronic current

$$K_\mu = \bar{u}_\Sigma(P)\Gamma_\mu u_\Lambda(p) \quad (5)$$

- ✓ **Ward-ID:**

$$K_\mu (P - p)^\mu = 0$$

C) Lepton current

$$j_\mu = \bar{u}(k_1)\gamma_\mu \nu(k_2) \quad (6)$$

Amplitude III

D) Amplitude:

$$M = \frac{1}{q^2} K_\mu j^\mu \tag{7}$$

E) Prob: $|M|^2$

$$\begin{aligned} |M|^2 = -\frac{64e^2}{M^4} & (2F_1\bar{F}_2 M(m_\Sigma q^2 + (k_2 \cdot P + k_1 \cdot P)\Delta) + \\ & 2F_1((k_2 \cdot P q^2 + m_\Sigma m_\Lambda) + k_1 \cdot P(q^2 - 4k_2 \cdot P))q^2 \\ & + F_2 M(2F_1(m_\Sigma q^2 + k_2 \cdot P m_\Lambda + k_1 \cdot P\Delta - k_2 \cdot P m_\Sigma)q^2 \\ & + \bar{F}_2 M(-2(k_1 \cdot P)^2 q^2 k_1 \cdot P - 2k_2 \cdot P q^2 + m_\Lambda m_\Sigma q^2)) \end{aligned} \tag{8}$$

$\Sigma^0 \rightarrow \Lambda\gamma$

Amplitude IV

A) $\Sigma - \Lambda$ vertex

$$\Gamma_\mu = e\left[\left(\gamma_\mu \frac{q^2}{M^2} - \frac{\Delta}{M^2} q_\mu\right) F_1 + i\sigma_{\mu\nu}\frac{q_\nu}{M} F_2\right] \tag{9}$$

- ✓ Assume: $F_1 \in \mathbb{R}$, $F_2 \in \mathbb{Z}$
- ✓ Usually $|F_2| < |F_1|$

B) Hadronic current

$$K_\mu = \bar{u}_\Sigma(P)\Gamma_\mu u_\Lambda(p) \tag{10}$$

- ✓ F_1 vanish

$$q_\mu \cdot \epsilon^\mu = 0 \Rightarrow ...q_\mu)F_1\epsilon^\mu = 0$$

- ✓ Only F_2 contribute to decay Width
- ✓ If $F_2 << F_1$, the dalitz decay may contribute more, i.e larger $\mathcal{B}(\Sigma \to e^+e^-\Lambda)$

Amplitude V

C) Amplitude:

$$M = eK_{\mu}\epsilon^{\mu} \tag{11}$$

D) Prob: $|M|^2$

$$|M|^2 \sim (P \cdot p)^2$$

Event Selection

I) Good charged track

- ✓ Vertex: $V_r < 1\ cm$, $V_z < 10\ cm$ (only aviable for electron)
- ✓ Polar angle: $cos\theta < 0.93$

II) Good photons

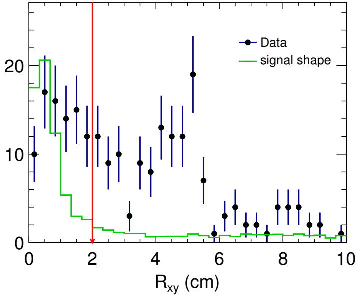
- ✓ Barrel: $cos\theta < 0.8$, $E_\gamma > 25$ MeV
- ✓ End Cap: $0.86 < cos\theta < 0.92$, $E_\gamma > 50$ MeV

III) Λ candidates:

- ✓ Mass: $[1.110, 1.121]$ GeV
- ✓ vertex fit: $\chi^2 < 100$
- ✓ No requirement on Second VertexFit

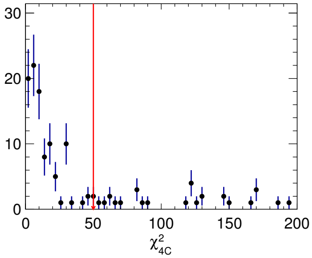
Veto gamma conversion

✓ Veto the events $R_{xy} > 2cm$

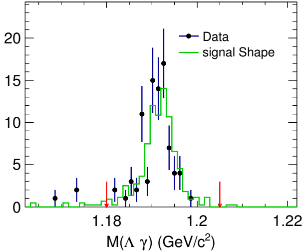


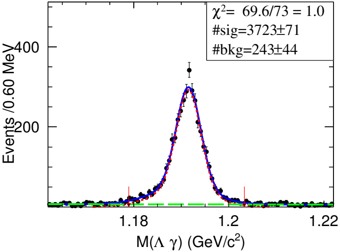
Requirement on Kenimatic Fit

✓ $\chi^2 < 50$



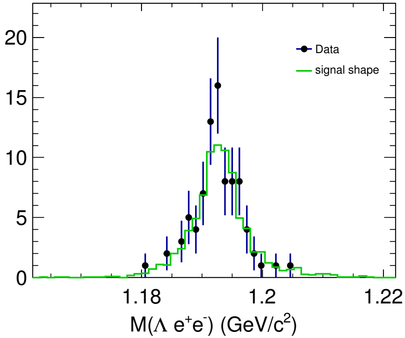
Requirement on $M(\Lambda\gamma)$





Signal

✓ Total signal: 84



Background

- ✓ Main background: γ conversion in

$$\Sigma^0 \to \Lambda\gamma$$

- ✓ Only 1 events found amongst 1M MC sample
- ✓ expect about 1.6 background in data

$\mathcal{B}(\Sigma \to \Lambda e^+ e^-)$

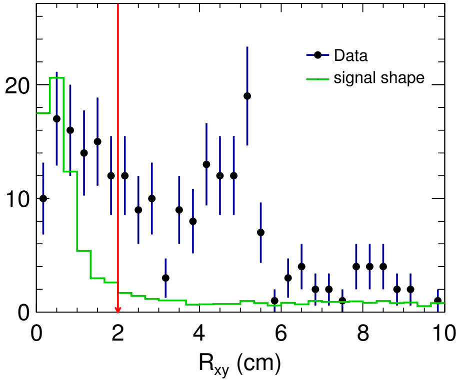
$$BF = \frac{n^{yield}}{N_{J/\psi} \cdot \mathcal{B}(J/\psi \to \Sigma^0\bar{\Sigma}^0)\mathcal{B}(\Lambda \to p\pi)\mathcal{B}(\bar{\Lambda} \to p\pi) \cdot \epsilon} \quad (12)$$

n^{yield}	83
$N_{J/\psi}$	$(1.310 \pm 0.007) \times 10^9$
ϵ	$0.39 \pm 0.01\%$

Assume $\mathcal{B}(\Sigma^0 \to \gamma\Lambda) = 96.4\%$

- ✓ $BF = (3.6 \pm 0.4)\%$
- ✓ Theory: 0.545 %

gamma conversion

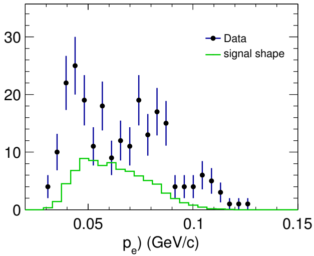


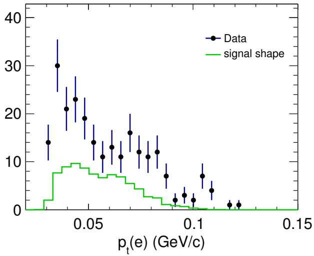
Next to

A) Check...

B) Analysis new J/ψ data collected during 2017-2018 to improve the measurement.

Back


30
20
10
0
0.05
0.1
0.15
Data
signal shape
p_e) (GeV/c)


40
30
20
10
0
0.05
0.1
0.15
Data
signal shape
p_t(e) (GeV/c)