\[ e^+ e^- \rightarrow \Lambda \Sigma^0 + c.c \]

Cross section measurement from threshold to 3.08 GeV

Zhang Hao

USTC

June 25, 2019
1. Motivation

2. BESIII and BEPCII

3. Monte Carlo Example Analysis

4. Result
One of the most challenging questions in contemporary physics is why and how quarks are confined into hadrons.

The study of hadron electric and magnetic structures can provide a key.

The electromagnetic form factors (EMFFs) have been a powerful tool in understanding the structure of nucleons.
Baryon’s Structure

- Electromagnetic Form Factors
  - fundamental hadron structure observables
  - describe the deviation from the point-like case
  - related to the charge and magnetization density
- EMFFs of nucleon can be studied in
  - elastic scattering
    - space-like, $e^- N \rightarrow e^- N$
    - $q^2 = (p_{e^-}^0 - p_{e^-}^i)^2 < 0$
    - $G_E$ and $G_M$ are real numbers
    - unstable, low-quality
  - annihilation
    - time-like, $e^+ e^- \rightarrow N\bar{N}, N\bar{N} \rightarrow e^+ e^-$
    - $q^2 = (p_{e^+}^0 + p_{e^-}^0)^2 > 0$
    - $G_E$ and $G_M$ are complex numbers
    - easy to analysis, a mount of data

\[
\sigma_{\text{Born}}(q^2) = \frac{4\pi\alpha^2\beta}{3q^2} \left[ |G_M(q^2)|^2 + \frac{1}{2\tau} |G_E(q^2)|^2 \right]
\]
Charged baryon pair

\[
\sigma(q^2) = \frac{4\pi\alpha^2\beta}{3q^2} C \left[ |G_M(q^2)|^2 + \frac{1}{2\tau} |G_E(q^2)|^2 \right]
\]
Neutral baryon pair

\[ \sigma(q^2) = ??? \]
BABAR’s result on $\Lambda \bar{\Sigma}^0$

BABAR has measured the cross section and form factor of $\Lambda \bar{\Sigma}^0$ process as shown below, but the accuracy is not very good.

$$\sigma_{\text{Born}}(q^2) = \frac{4\pi \alpha^2 \beta}{3q^2} \left[ |G_M(q^2)|^2 + \frac{1}{2\tau} |G_E(q^2)|^2 \right]$$

$$|F(q^2)|^2 = \frac{2\tau |G_M(q^2)|^2 + G_E(q^2)|^2}{2\tau + 1}$$
BEPCII

$E_{\text{beam}}$: 1.0-2.3 GeV
$\sigma_E$: $5.16 \times 10^{-4}$
$L$: $1.0 \times 10^{33}$ cm$^{-2}$s$^{-1}$ @3770

BES

Linac

Storage ring

BEPCII = Beijing Electron Positron Collider II
**Main Drift Chamber**
Small cell, 43 layer
\[ \sigma_{xy} = 130 \, \mu m, \, dE/dx \sim 6\% \]
\[ \sigma_p/p = 0.5\% \text{ at } 1 \text{ GeV} \]

**Muon Counter**
Resistive plate chamber
Barrel: 9 layers
Endcaps: 8 layers
\[ \sigma_{\text{spatial}} = 1.48 \text{ cm} \]

**Time Of Flight**
Plastic scintillator
\[ \sigma_T(\text{barrel}): \, 80 \, \text{ps} \]
\[ \sigma_T(\text{endcap}): \, 110 \, \text{ps} \]

**Electromagnetic Calorimeter**
CsI(Tl): \( L = 28 \, \text{cm} \) (15\( X_0 \))
Energy range: 0.02-2\text{GeV}
Barrel \( \sigma_E = 2.5\% \), \( \sigma_1 = 6\, \text{mm} \)
Endcap \( \sigma_E = 5.0\% \), \( \sigma_1 = 9\, \text{mm} \)

**BESIII = Beijing Spectrometer III**
100K $e^+ e^- \rightarrow \Lambda \bar{\Sigma}^0$ MC examples
Reaction chain

Charged Tracks

$|V_{xy}| < 10\,\text{cm}, |V_z| < 30.0\,\text{cm}, |\cos \theta| < 0.92$

Particle Identification

$N(p) = N(\pi^-) = 1$ or $N(\bar{p}) = N(\pi^+) = 1$

VertexFit and SecondVertexFit

$$\chi^2_{\text{VertexFit}} + \chi^2_{\text{SecondVertexFit}} < 50$$

$$\frac{\delta L}{\sigma \delta L} > 2$$

$$1.11\,\text{GeV}/c^2 < m(\Lambda) < 1.12\,\text{GeV}/c^2$$

$$1.11\,\text{GeV}/c^2 < m(\bar{\Lambda}) < 1.12\,\text{GeV}/c^2$$
Vertex and Second Vertex Fit

- Invariant mass of $\Lambda$ and $\bar{\Lambda}$
- Distribution of $L/\delta L$
- $\chi^2_{\text{Vertex Fit}} + \chi^2_{\text{Second Vertex Fit}}$

$e^+e^- \rightarrow \Lambda\Sigma^0 + c.c$
Recoil Energy

- From the system and reconstructed $\Lambda(\bar{\Lambda})$'s four momentum, the miss $\bar{\Sigma}(\Sigma)$'s four momentum can be calculated.

\[ p_{\text{miss}} = p_{\text{cm}} - p_{\text{rec}} \]

- because the process is two-body process, the energy of final state could be exactly calculated

\[ E_{\Lambda} = \frac{s + m_{\Lambda}^2 - m_{\Sigma}^2}{2\sqrt{s}}, \quad E_{\Sigma} = \frac{s + m_{\Sigma}^2 - m_{\Lambda}^2}{2\sqrt{s}} \]

- From miss $\bar{\Sigma}(\Sigma)$'s four momentum, we can get $\bar{\Sigma}(\Sigma)$'s invarient mass.
Distribution of sigma

invariant mass of $\Sigma^0$
show the formula which calculate the cross section

\[ \sigma^B = \frac{N^{signal}}{\mathcal{L} \cdot \varepsilon \cdot (1 + \delta) \cdot Br} \]

- \((1 + \delta)\) is ISR correction and vacuum polarization factor.
- \(N^{signal}\) is the observed signal
- \(\varepsilon\) is the detection efficiency
- \(\mathcal{L}\) is the luminosity.
- \(Br\) is the Branch faction
interpolate the BABAR's result to get cross sections of every energy point and calculate the fake signal number

use the fake signal number to calculate the fake cross section's error

<table>
<thead>
<tr>
<th>$\sqrt{s}$ (GeV)</th>
<th>$\mathcal{L}$ (pb$^{-1}$)</th>
<th>$\varepsilon$</th>
<th>$(1 + \delta)$</th>
<th>$Br$</th>
<th>$N_{data}$ (BABAR)</th>
<th>$\sigma$ (BABAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3864</td>
<td>22.588</td>
<td>0.0909</td>
<td>0.924</td>
<td>63.9%</td>
<td>50.9308 ± 7.1366</td>
<td>42.0113 ± 5.8868</td>
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<tr>
<td>2.396</td>
<td>66.893</td>
<td>0.1150</td>
<td>0.940</td>
<td>63.9%</td>
<td>187.1779 ± 13.681</td>
<td>40.5086 ± 2.9609</td>
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<tr>
<td>2.500</td>
<td>1.099</td>
<td>0.2516</td>
<td>1.605</td>
<td>63.9%</td>
<td>6.6305 ± 2.5750</td>
<td>23.3809 ± 9.0801</td>
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<tr>
<td>2.6444</td>
<td>33.650</td>
<td>0.3124</td>
<td>1.257</td>
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<td>28.6831 ± 5.3557</td>
<td>3.39699 ± 0.6343</td>
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<tr>
<td>2.6464</td>
<td>34.064</td>
<td>0.3127</td>
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<td>63.9%</td>
<td>28.0874 ± 5.2998</td>
<td>3.29597 ± 0.6219</td>
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<tr>
<td>2.700</td>
<td>1.035</td>
<td>0.3423</td>
<td>1.151</td>
<td>63.9%</td>
<td>0.5482 ± 0.7404</td>
<td>2.10404 ± 2.8416</td>
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<tr>
<td>2.800</td>
<td>1.008</td>
<td>0.3871</td>
<td>1.060</td>
<td>63.9%</td>
<td>0.7665 ± 0.8755</td>
<td>2.9 ± 3.3125</td>
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<tr>
<td>2.900</td>
<td>105.53</td>
<td>0.4113</td>
<td>1.016</td>
<td>63.9%</td>
<td>70.3430 ± 8.3871</td>
<td>2.49627 ± 0.2976</td>
</tr>
<tr>
<td>2.950</td>
<td>15.960</td>
<td>0.4202</td>
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<td>63.9%</td>
<td>10.0730 ± 3.1738</td>
<td>2.32497 ± 0.7326</td>
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<tr>
<td>2.981</td>
<td>16.046</td>
<td>0.4280</td>
<td>1.025</td>
<td>63.9%</td>
<td>10.2006 ± 3.1938</td>
<td>2.26772 ± 0.7100</td>
</tr>
<tr>
<td>3.000</td>
<td>15.859</td>
<td>0.4276</td>
<td>1.004</td>
<td>63.9%</td>
<td>9.8290 ± 3.1351</td>
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<tr>
<td>3.020</td>
<td>17.315</td>
<td>0.4296</td>
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<td>63.9%</td>
<td>10.1296 ± 3.1827</td>
<td>2.27682 ± 0.7154</td>
</tr>
<tr>
<td>3.080</td>
<td>126.21</td>
<td>0.4290</td>
<td>1.008</td>
<td>63.9%</td>
<td>88.3415 ± 9.3990</td>
<td>2.5331 ± 0.2695</td>
</tr>
</tbody>
</table>
Expected Result

- Interpolation of BABAR
- BABAR
- $\Lambda\Sigma^0$ Threshold

$e^+e^- \rightarrow \Lambda\Sigma^0 + c.c$
We are able to extract $e^+e^- \rightarrow \Lambda\bar{\Sigma}^0 + c.c.$ signal process from Monte Carlo and get the needed efficiency. The next is to apply the algorithm on the BESIII’s experimental data, which has been done but not shown in the picture.

The calculated error is lower than BABAR as expected.

We are now paying attention to cross section measurement near the threshold and expect to also give a better result.

Thank you!!!