The Study of $\psi(2S) \to$ Baryon Pairs

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Outline

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2. Event Selection and Analysis
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Introduction

Motivation

1. Check the results of the BRs of $\psi' \to B\bar{B}$
2. Measure the α value of angular distribution in $\psi' \to p\bar{p}$ decay, and check the theory model;
3. Check the "12% rule" in hardron decay.

In our measurement, the following decay processes are included:

$$\psi' \to p\bar{p}$$
$$\psi' \to \Lambda\bar{\Lambda} \to p\pi^-\bar{p}\pi^+$$
$$\psi' \to \Sigma^0\bar{\Sigma}^0 \to \Lambda\gamma\bar{\Lambda}\gamma \to p\pi^-\gamma\bar{p}\pi^+\gamma$$
$$\psi' \to \Xi^-\bar{\Xi}^+ \to \Lambda\pi^-\bar{\Lambda}\pi^+ \to p\pi^-\pi^-\bar{p}\pi^+\pi^+$$

Event Selection and Analysis

Criteria for charged track.

A charged particle is considered to be a well reconstructed charged track if the following requirements are satisfied: (1).Good MDC tracks; (2).Track Charge = $\pm$1; (3).MFIT = 2; (4).Rxy$<$0.02m, z$<$0.2m(only for $\psi' \to p\bar{p}$); (5).Pxy$>$0.07GeV; (6).$|\cos(\theta)| < 0.8$.

And in each final state of the four investigated channels, the net charge zero is required.

Criteria for good γ.

A neutral cluster is considered to be a good photon candidate when the following requirements are satisfied:

(1). Detected by BSC;

(2). $\theta_{xy} > 15^o$: θ_{xy} is the angle between the nearest charged track and the cluster in the xy-plane;

(3). $N_{hit} \leq 6$: N_{hit} is the first hit in BSC;

(4). $\theta_{xy}^{emit} < 37^o$: θ_{xy}^{emit} is the angle between the cluster development direction in the BSC and the photon emission direction in xy-plane.

(5). $E_\gamma > 0.05GeV$.

Event Selection and Analysis

The selection of $\psi' \to p\bar{p}$:

1. Two good charged tracks;
2. PID: $\Delta_t(i) < \Delta_t(j)$, $i = p(\bar{p})$; $j = \pi$, or K, and $TOF_{\text{quality}} = 1$ where $\Delta_t(i,j) = |t_{\text{meas}} - t_{\text{exp}}(i,j)|$;
3. $|t_+ - t_-|$ <4 ns;
4. $\theta_{acol} < 5^o$;
5. E_+ <0.75(GeV);
6. $3.556 < E_{p\bar{p}} < 3.816 GeV$;
7. $|P_- - P_{\bar{p}}| < 0.15 GeV$ (From M.C. simulation, the resolution of $P_{\bar{p}}$ is about 50MeV);

Event Selection and Analysis

The analysis of $\psi' \to p\bar{p}$:

1. $\psi' \to p\bar{p}$ events: [Scatter Plot]
2. Background estimation: the main backgrounds are from 2-prong without photon (or with low-energy photon) processes, such as Bhabha, Dimu [Table]
3. The fitting of P_p: The data are fitted by a MC histogram for the signal plus a background function which corresponds to the simulated background events and a flat distribution to describe the remaining background.$N_{obs.} = 1618.2 \pm 43.4$.[Figure]
4. Angular distribution. [Detail]

Event Selection and Analysis

The selection of $\psi' \to \Lambda\bar{\Lambda}$:

1. Four good charged tracks;
2. PID: two of four positive and negative charged tracks with higher momentum are assumed to be proton and antiproton; the other two tracks are regarded as π^+ and π^-;
3. Secondary vertex: the two pair of $p\pi$s should pass the routine of secondary vertex algorithm, and find the secondary vertex successfully[10], and the sum of decay lengths of Λ and $\bar{\Lambda}$ should be greater than 0.02m;
4. $3.60GeV < E_{\Lambda\bar{\Lambda}} < 3.81GeV$;
5. $P_{\text{miss}} < 0.18GeV$;
6. $|M_{\bar{p}\pi^+} - M_{\Lambda}| < 0.012GeV$. (From M.C. simulation the resolution of M_{Λ} is about 4MeV)

Event Selection and Analysis

The analysis of $\psi' \to \Lambda\bar{\Lambda}$:

1. $\psi' \to \Lambda\bar{\Lambda}$ events: [Scatter Plot]
2. Background estimation: the main backgrounds are from the processes which include Λ and $\bar{\Lambda}$,[Table], $\psi' \to \Sigma^0\bar{\Sigma}^0$, and $\psi' \to \Lambda\bar{\Sigma}^0 + c.c.$ will also create a peak under the signal peak.
3. The fitting of $M_{p\pi^-}$: the data are fitted by a histogram of the signal shape from MC plus a background function which describes the simulated backgrounds and a flat distribution to describe any remaining sources.$N_{obs.} = 337.2 \pm 19.9$.[Figure]

Event Selection and Analysis

The selection of $\psi' \to \Sigma^0\bar{\Sigma}^0$:

1. Four good charged tracks;
2. PID and Secondary vertex: the same as $\psi' \to \Lambda\bar{\Lambda}$;
3. $P_{\text{miss}} < 0.25GeV$;
4. Not less than 2 good γs in the event:
5. $\chi^2_{4C-fit}(p\bar{p}\pi^+\pi^-\gamma\gamma) < 20$, and the two γs will be identified by the least $\sqrt{(M_{p\pi^-\gamma} - M_{\Sigma^0})^2 + (M_{\bar{p}\pi^+\gamma} - M_{\bar{\Sigma}^0})^2}$;
6. $|M_{\bar{p}\pi^+\gamma} - M_{\bar{\Sigma}^0}| < 0.036GeV$. (From M.C. simulation the resolution of $M_{\bar{\Sigma}^0}$ is about 12MeV)

Event Selection and Analysis

The analysis of $\psi' \to \Sigma^0\bar{\Sigma}^0$:

1. $\psi' \to \Sigma^0\bar{\Sigma}^0$ events: [Scatter Plot]
2. Backgrounds estimation: the main backgrounds are from the process which include Λ and $\bar{\Lambda}$, such as $\psi' \to \Lambda\bar{\Lambda}$, $\psi' \to \gamma\chi_{CJ(J=0,1,2)} \to \gamma\Lambda\bar{\Lambda}$, $\psi' \to \Xi^0\bar{\Xi}^0$, $\psi' \to \Lambda\bar{\Sigma}^0 + c.c.$, $\psi' \to \Sigma^0\bar{\Xi}^0 + c.c.$, etc. [Table]
3. The fitting of $M_{p\pi^-\gamma}$: the data are fitted by a histogram of the signal shape from MC plus a background function which describes the simulated backgrounds and a flat distribution to describe any remaining sources.$N_{obs.} = 59.1 \pm 9.1$.[Figure]

Event Selection and Analysis

The selection of $\psi' \to \Xi^-\bar{\Xi}^+$:

1. Six good charged tracks;
2. PID: two of six charged tracks with higher momentum are assumed to be proton and antiproton; the other four tracks are regarded as πs;
3. Secondary vertex: loop the 4 πs to combine with p and $\bar{p}$, it is required that there must be two pair of $p\pi$s in the six final particles successfully pass the secondary vertex algorithm, if there are more than one possibility, we calculate the invariant mass of each pair of $p\pi$s, the one with the least $\sqrt{(M_{p\pi^-} - M_\Lambda)^2 + (M_{\bar{p}\pi^+} - M_\Lambda)^2}$ will be the candidate;
4. $3.593GeV < E_{\Xi^-\bar{\Xi}^+} < 3.779GeV$;
5. $P_{\text{miss}} < 0.15GeV$;
6. $|M_{\bar{p}\pi^+\pi^+} - M_{\bar{\Xi}^+}| < 0.018GeV$. (From M.C. simulation the resolution of M_{Ξ^+} is about 6MeV)

Event Selection and Analysis

The analysis of $\psi' \to \Xi^-\bar{\Xi}^+$:

1. $\psi' \to \Xi^-\bar{\Xi}^+$ events: [Scatter Plot]
2. Backgrounds estimation: the main backgrounds are from the process which include Λ and $\bar{\Lambda}$, such as $\psi' \to \pi^+\pi^- J/\psi \to \pi^+\pi^-\Lambda\bar{\Lambda}$, and $\psi' \to \Sigma(1385)^+\bar{\Sigma}(1385)^+ \to \Lambda\bar{\Lambda}\pi^+\pi^- + c.c.$, etc. [Table]
3. The fitting of $M_{p\pi^-\pi^-}$: the data are fitted by a histogram of the signal shape from MC plus a background function which describes the simulated backgrounds and a flat distribution to describe any remaining sources.$N_{obs.} = 67.4 \pm 8.9$. [Figure]

Systematic errors(%)

Source	$p\bar{p}$	$\Lambda\bar{\Lambda}$	$\Sigma^0\bar{\Sigma}^0$	$\Xi^-\bar{\Xi}^+$
MDC tracking[Detail]	4	4.5	4.5	5.7
Particle identification	2.0	\	\	\
Time of flight	0.9	\	\	\
BSC deposit energy	1.2	\	\	\
Acol angle	0.6	\	\	\
Λ vertex finding[Detail]	\	1.4	1.4	1.4
Sum decay length[Detail]	\	1.0	1.0	\
ECM region and recoiling mass	1.1	0.6	\	1.6
P_{miss} region	\	1.6	0.2	1.7
γ tracking	\	\	4	\
Kinematic fit[Detail]	\	\	7.6	\
Background	\	1.0	2.3	0.2
Continuum data	0.8	1.0	\	\
α value[Detail]	2.0	6.5	7.6	6.8
M.C.sample(G/F)	2.2	0.5	\	1.4
M.C. statistics	0.3	0.2	0.1	0.1
Total number of ψ'	4	4	4	4
Total error	7.3	9.4	13.4	10.3

Results and Summary

Table 1: Branching ratios of $\psi' \to B\bar{B}(\times 10^{-4})$

Results	$p\bar{p}$	$\Lambda\bar{\Lambda}$	$\Sigma^0\bar{\Sigma}^0$	$\Xi^-\bar{\Xi}^+$
PDG2004	2.07 ± 0.31	1.81 ± 0.34	1.2 ± 0.6	0.94 ± 0.31
BES-I[3]	$2.16 \pm 0.15 \pm 0.36$	$1.81 \pm 0.20 \pm 0.27$	$1.2 \pm 0.4 \pm 0.4$	$0.94 \pm 0.27 \pm 0.15$
CLEO-C[6]	$2.87 \pm 0.12 \pm 0.15$	$3.28 \pm 0.23 \pm 0.25$	$2.63 \pm 0.35 \pm 0.21$	$2.38 \pm 0.30 \pm 0.21$
BES-II	$3.36 \pm 0.09 \pm 0.25$	$3.39 \pm 0.20 \pm 0.32$	$2.35 \pm 0.36 \pm 0.32$	$3.03 \pm 0.40 \pm 0.32$

From the Table, the BRs of this measurement are in agreement with the results published by the CLEO-C within 2σ for $p\bar{p}$ and within 1σ for the other three channels. The differences of the BRs between current measurements and those of BES-I are 2.5σ, 3.1σ, 1.5σ, 3.5σ for the four channels, respectively.

The angular distribution parameter α for $\psi' \to p\bar{p}$ is measured to be $0.85 \pm 0.24 \pm 0.04$, which is in agreement within 1σ with the E835 result, and close to Carimaloą́s prediction.

The end

Thank you!

=== *Wish you a happy holiday!* ===

About the angular distribution

The angular distribution of $\psi' \rightarrow B_8 \bar{B}_8$ can be written as:

$$\frac{dN}{dcos\theta} \propto 1 + \alpha cos^2\theta$$

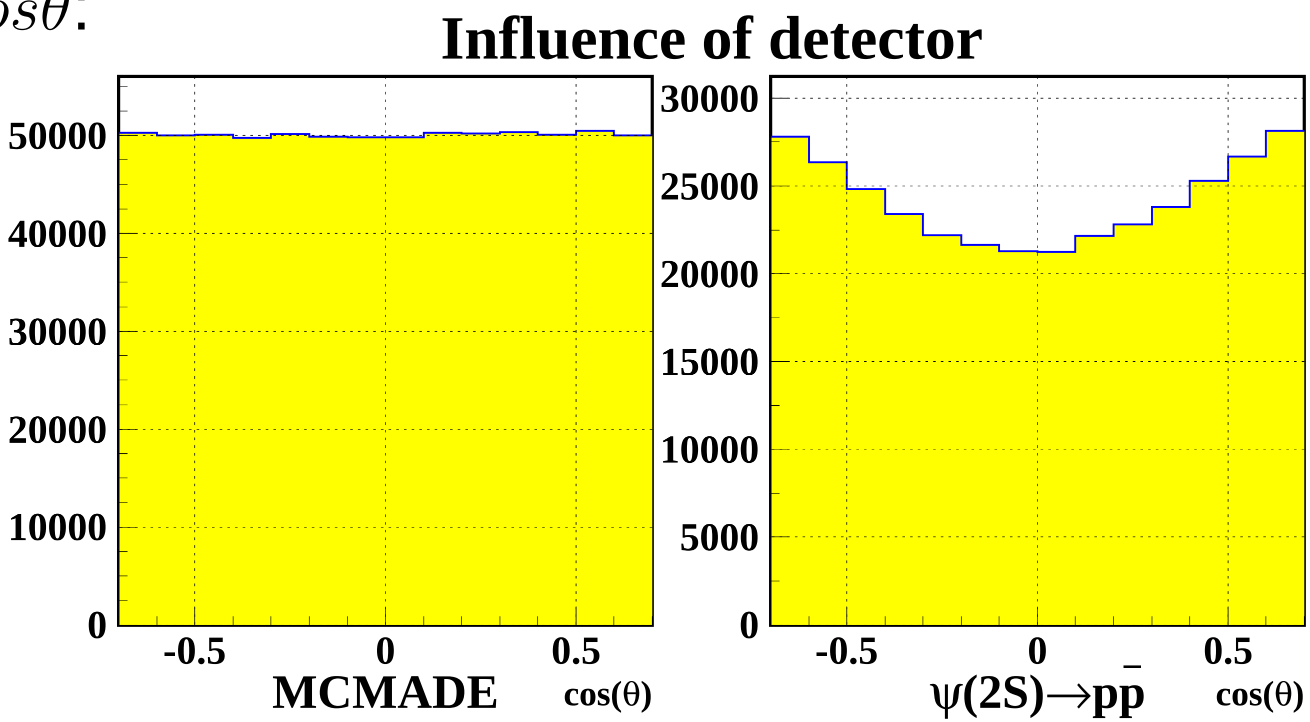
But considering the efficiency of Monte Carlo simulation(ϵ_{MC}) and efficiency correction of M.C.(f_c), the angular distribution of data should be written as:

$$f(cos\theta) \propto (1 + \alpha cos^2\theta) \times \epsilon_{MC} \times f_c$$

Where θ is the angle between proton and beam direction in the center-of-mass(CM) system.

The eff. of M.C.(ϵ_{MC})

In order to get the efficiency of M.C., a 500,000 M.C. sample (v10403) is generated by HOWL generator. Before and after the event selection, the distribution of $cos\theta$ is isotropic and angle-dependent, respectively, the ratio between these two figures is the efficiency of M.C. varying with $cos\theta$:



The eff. corr. of M.C.(f_c) I

The efficiency correction f_c is caused by the difference between measured value and expected value. If Monte Carlo sample cannot simulate the physics process perfectly, the difference between data and MC will show the necessity to do this correction. The correction function f_c includes the correction of each cut, defined as:

$$f_c = \frac{\epsilon_{Data}}{\epsilon_{MC}} = \prod_i \frac{\epsilon_{Data}}{\epsilon_{MC}}(i)$$

$$i = PID_+,\ PID_-,\ E_+,\ E_p + E_{\bar{p}},\ \theta_{acol},\ P_{\bar{p}}[4].$$

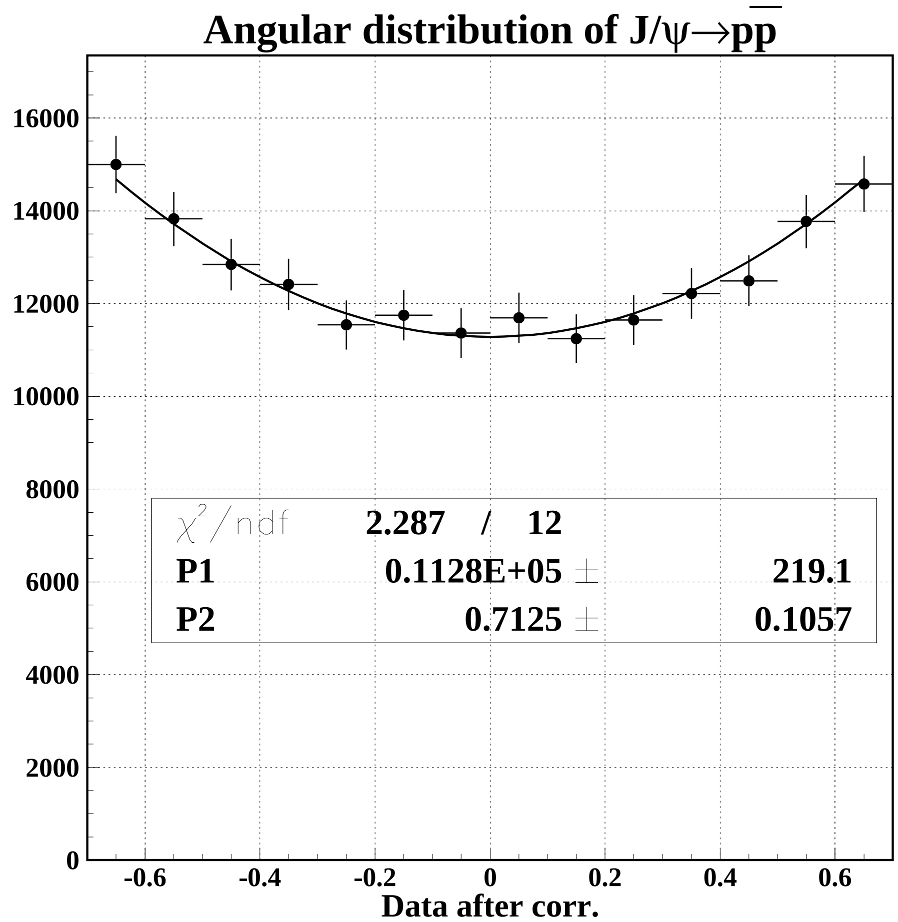
Then the corrected efficiency of M.C. is:

$$\epsilon'_{MC} = \epsilon_{MC} \times f_c$$

The eff. corr. of M.C.(f_c) II

A pure $\psi' \to p\bar{p}$ data sample and its corresponding M.C. sample are necessary to get the ϵ_{Data} and ϵ_{MC} respectively. But the statistics of $\psi' \to p\bar{p}$ events is not enough to do this job.

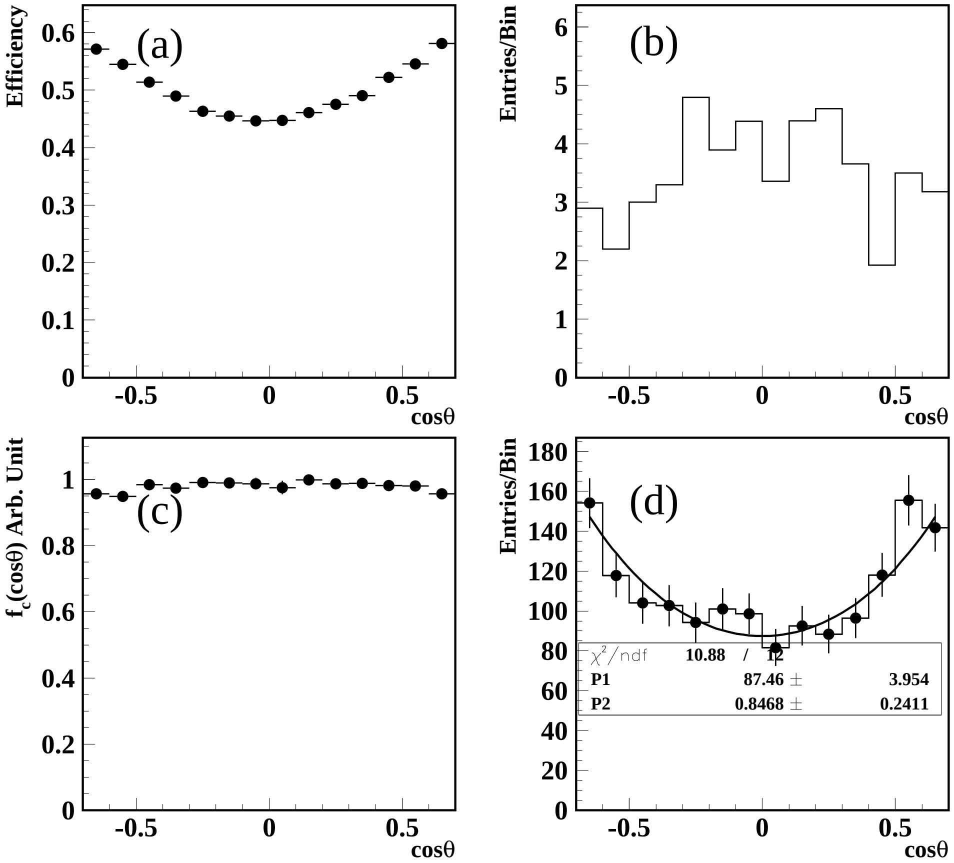
Here the channel $J/\psi \to p\bar{p}$ is chosen as the reference channel, because it has the similar decay process, the same final particles and it is easy to get the pure sample. Here, all the cuts used in $\psi' \to p\bar{p}$ will be used to the $J/\psi \to p\bar{p}$ equivalently.



The α value

Figure (a) is the efficiency of M.C.(ϵ_{MC}); (b) is distribution of backgrounds in different angle; (c) is the efficiency correction of M.C.(f_c); (d) is the angular distribution of real data.

The second fitting parameter is the α value of angular distribution. Here $\alpha = 0.85 \pm 0.24$



The sys. err. of α value

Source	error(%)
MDC Wire Resolution Model	2.7
Efficience Correction Curve	2.3
Performance of Detector	2.2
total	4.2

So, in the preliminary measurement, the α value of the angular distribution in $\psi' \rightarrow p\bar{p}$ is:

$$0.85 \pm 0.24(stat.) \pm 0.04(sys.)$$

[Back]

Figure I

Scatter plot of the P_+ and P_-[Back.]

PID, cosmic ray exclusion and multi-body Bg. exclusion have been done.

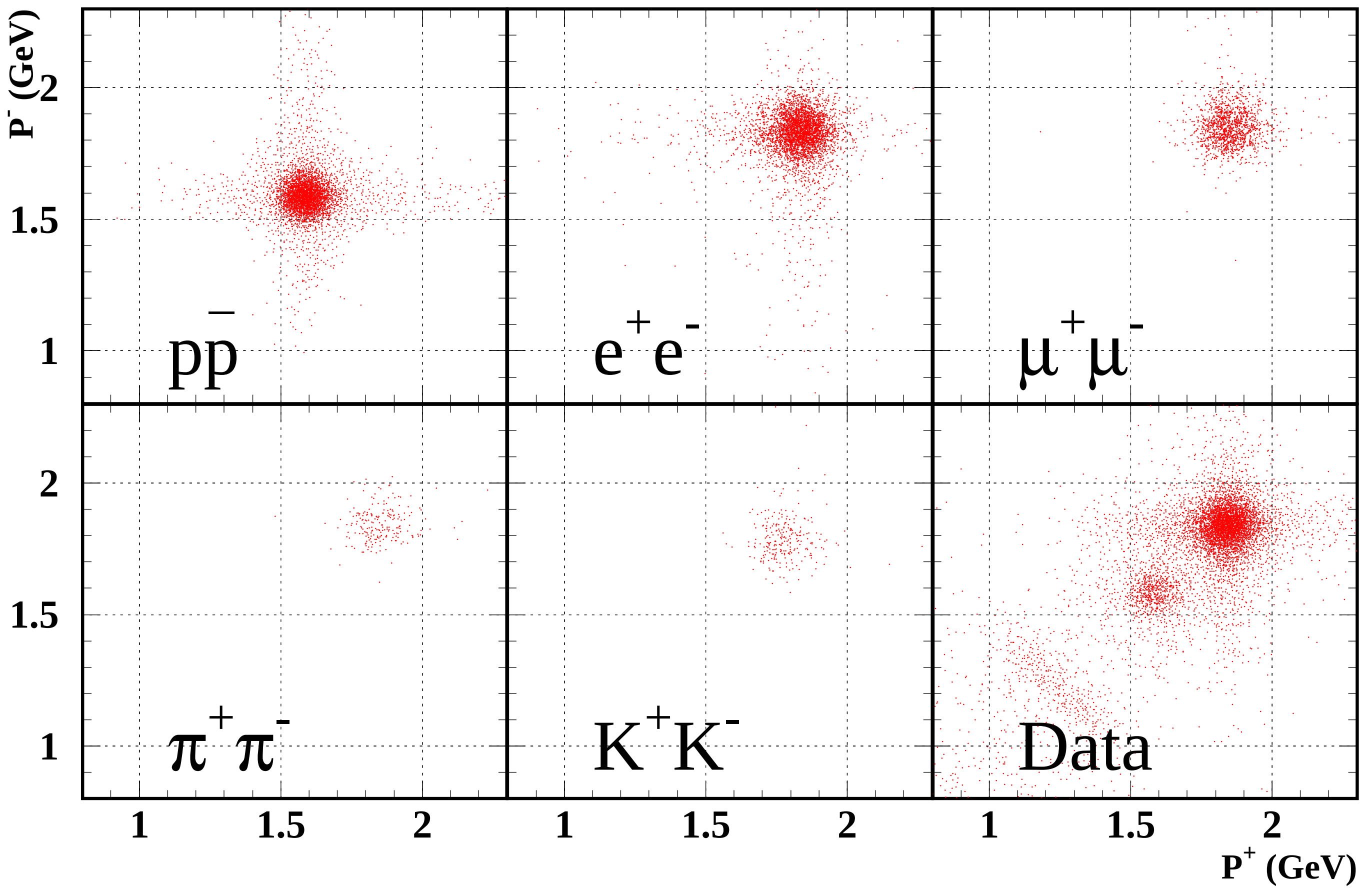


Figure II

Scatter plot of the M($p\pi^-$) and M($\bar{p}\pi^+$) [Back.]

Only the secondary vertex finding has been done.

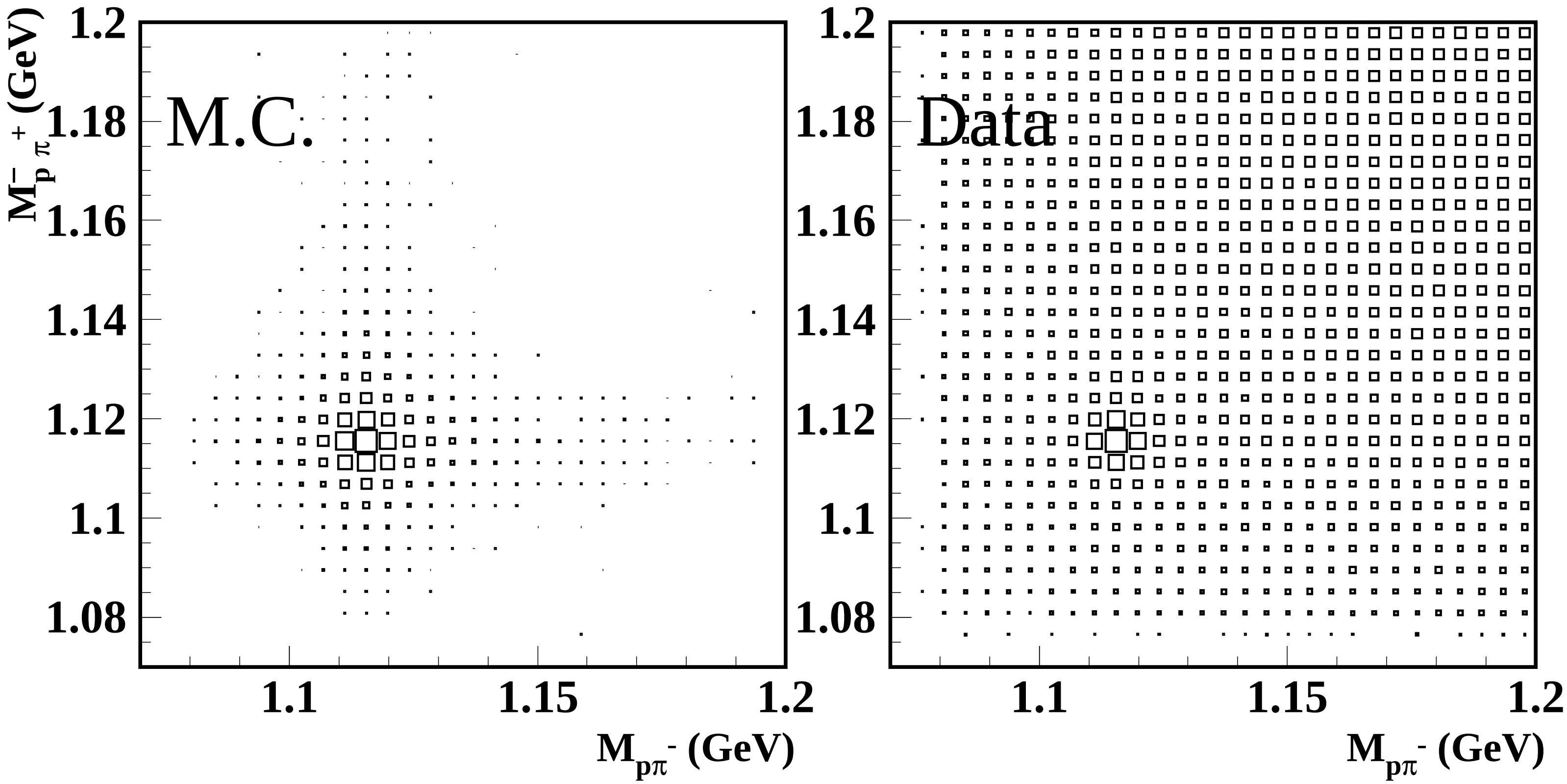


Figure III

Scatter plot of the M($p\pi^-\gamma$) and M($\bar{p}\pi^+\gamma$) [Back.]

The secondary vertex finding and kinematic fit have been done.

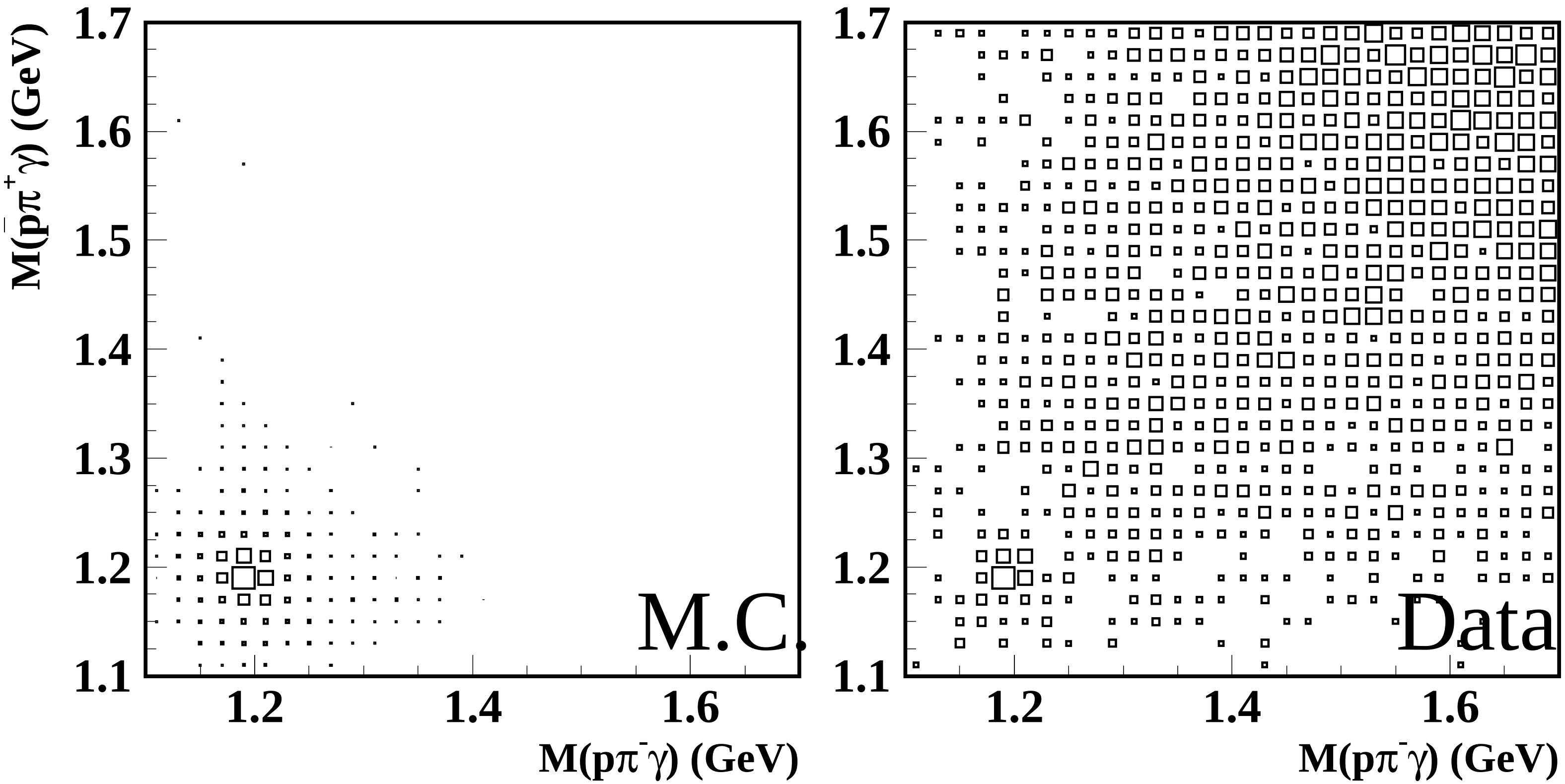


Figure IV

Scatter plot of the M($p\pi^-\pi^-$) and M($\bar{p}\pi^+\pi^+$) [Back.]

Only the secondary vertex finding has been done.

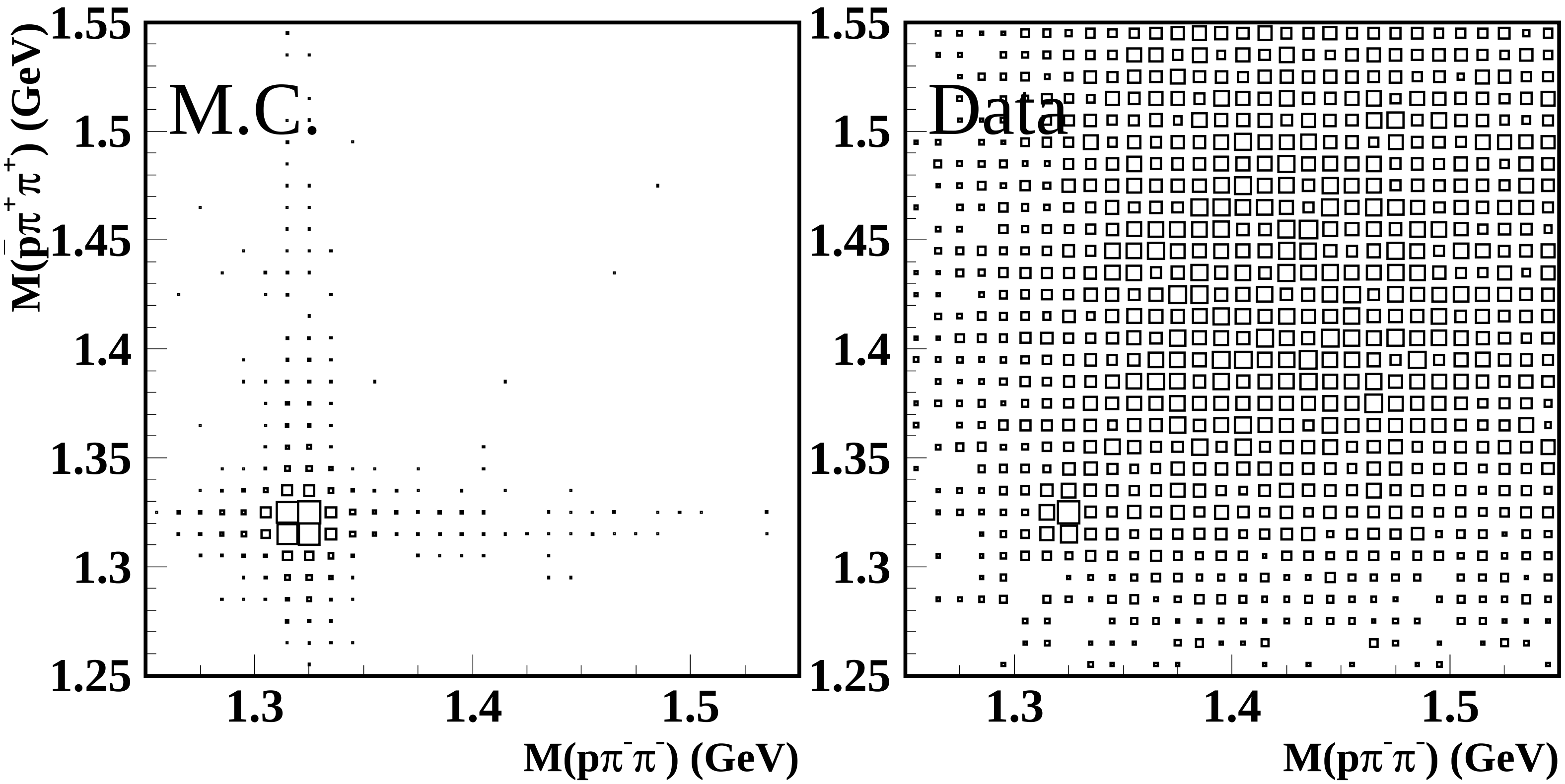
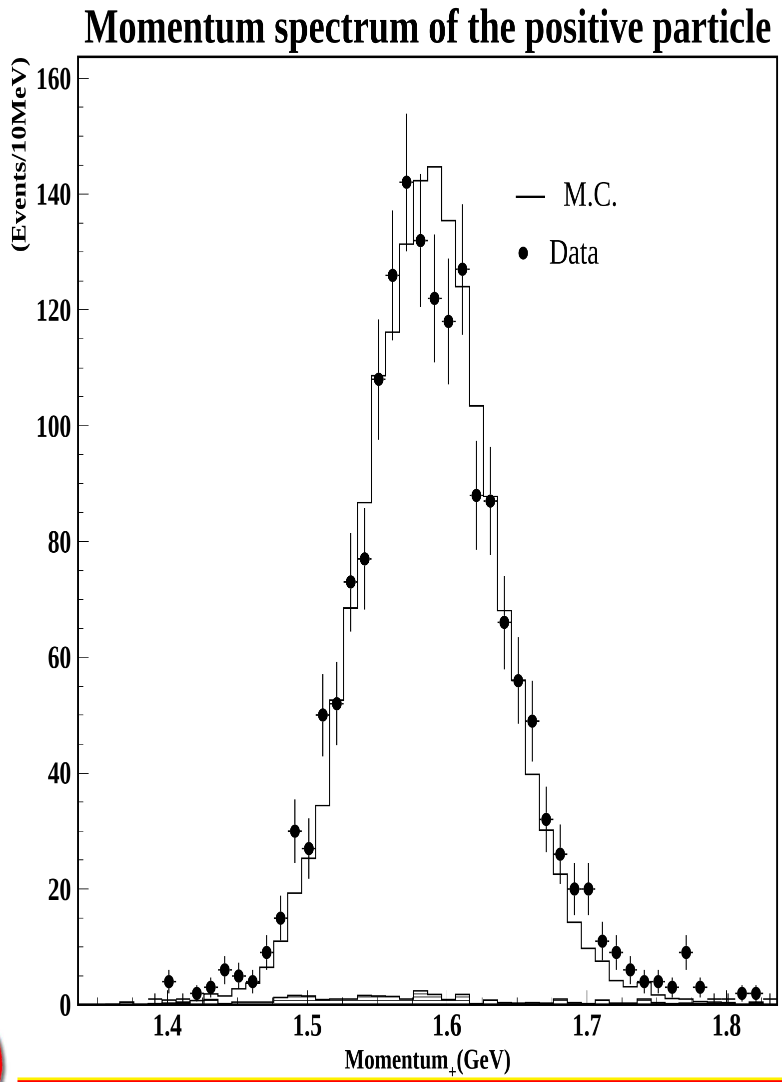


Figure V

Momentum distribution of proton and fitting[Back.]



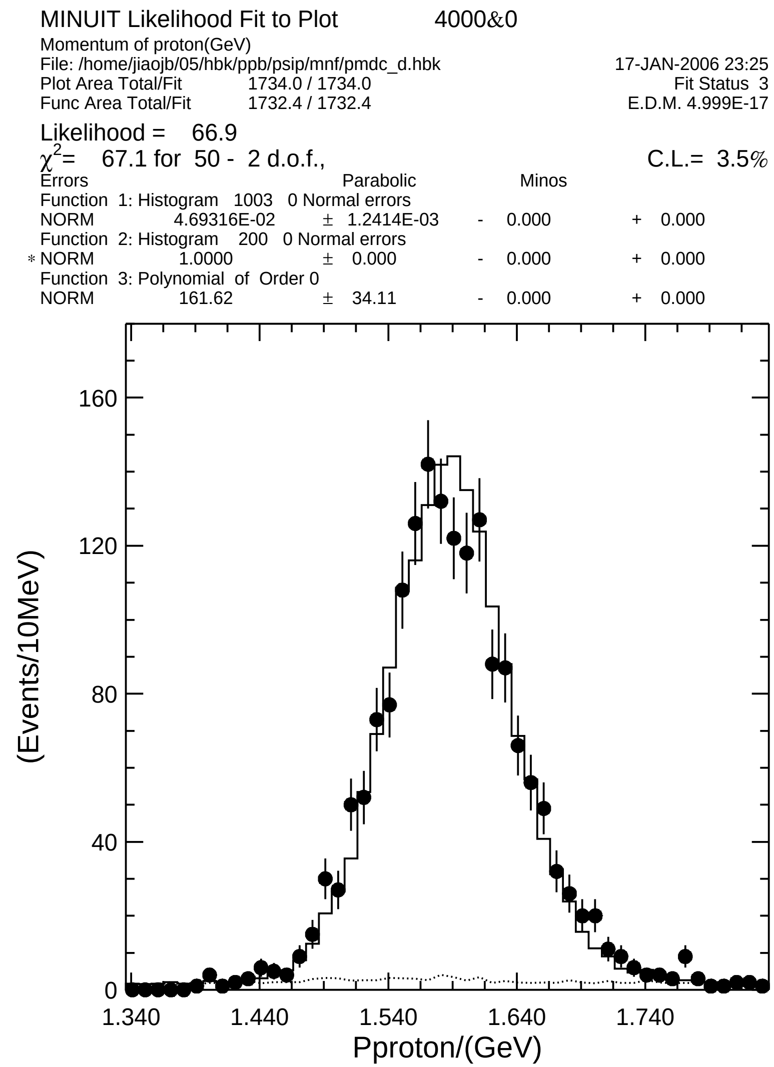
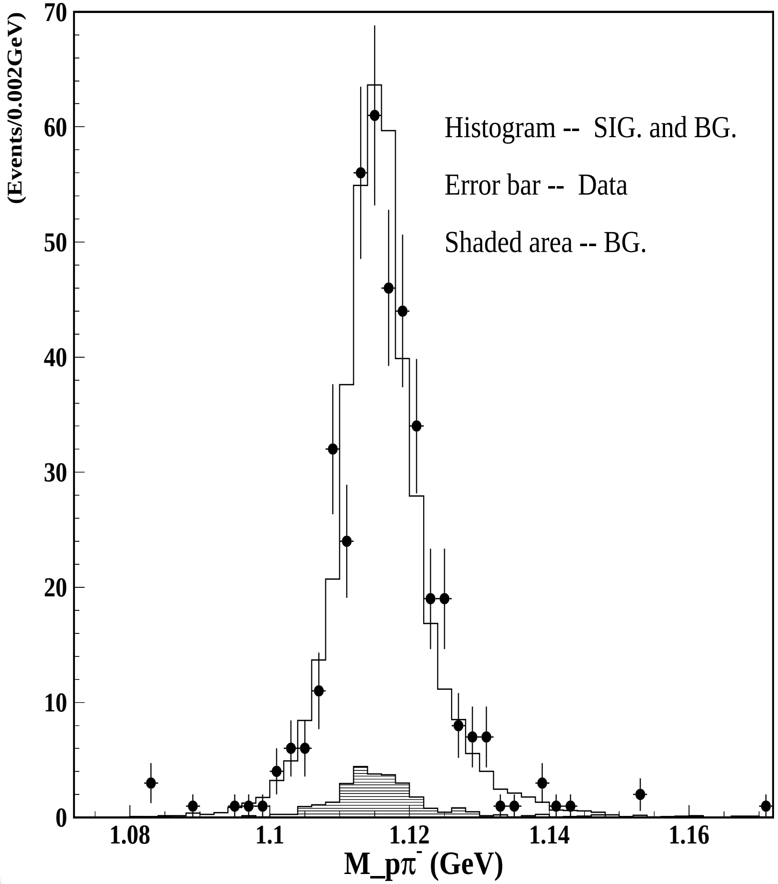


Figure VI

Mass spectrum of Λ and fitting[Back.]



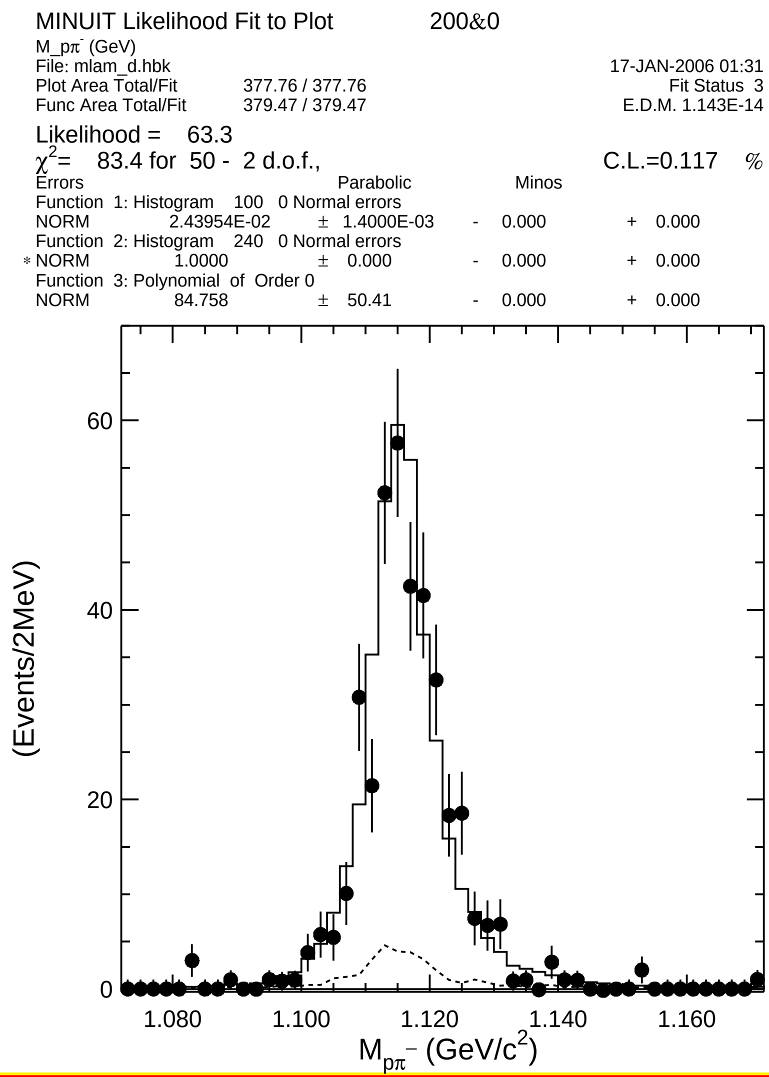
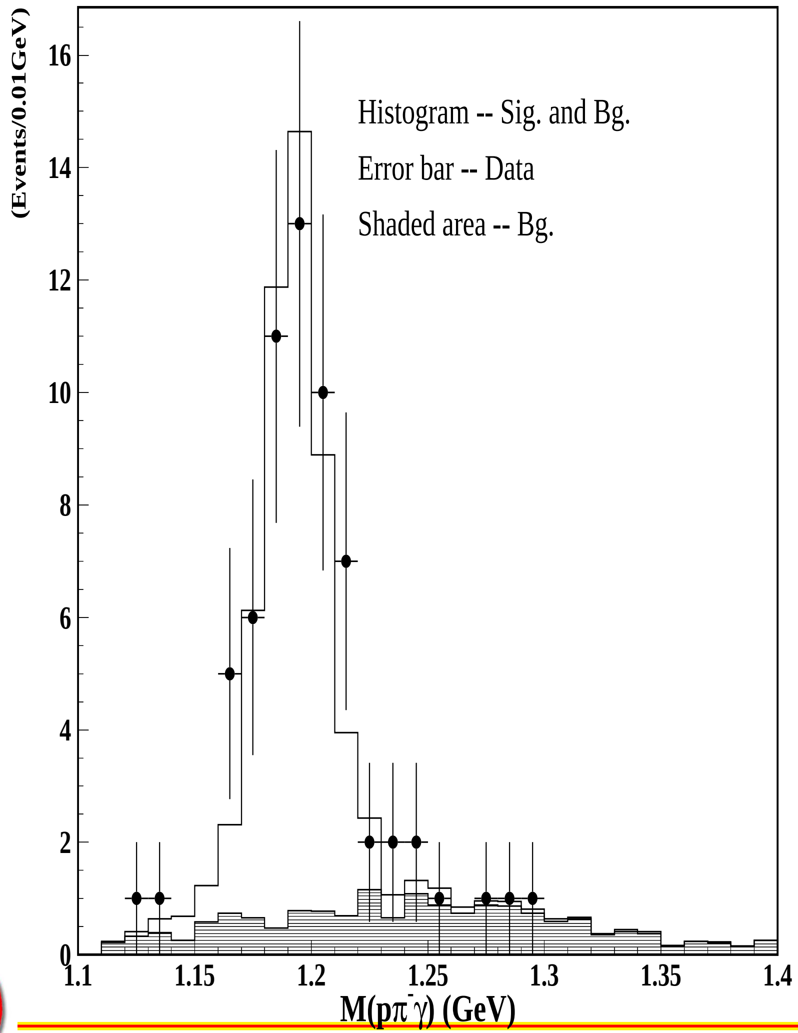


Figure VII

Mass spectrum of Σ^0 and fitting[Back.]



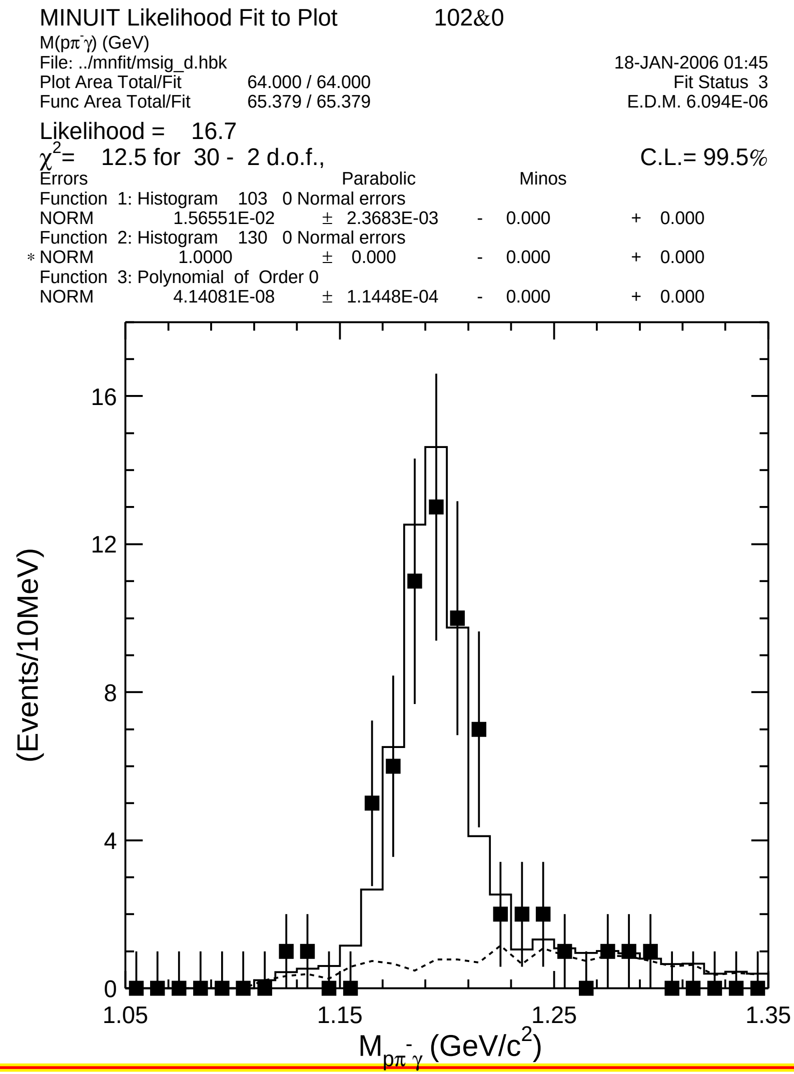
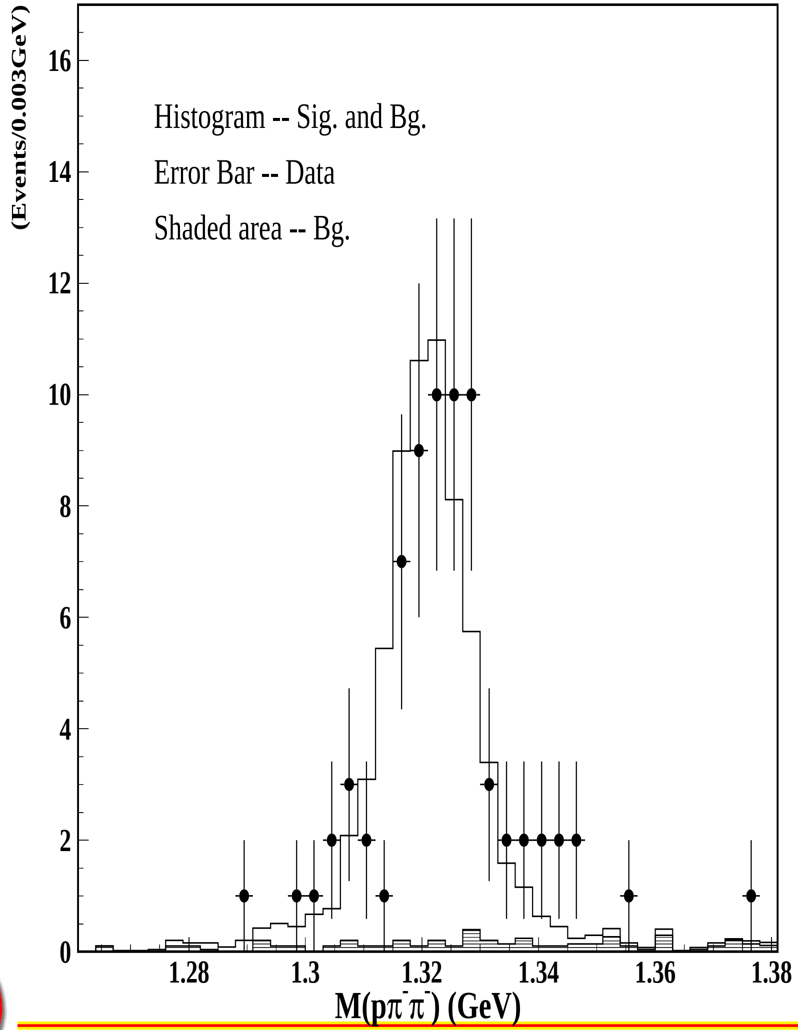
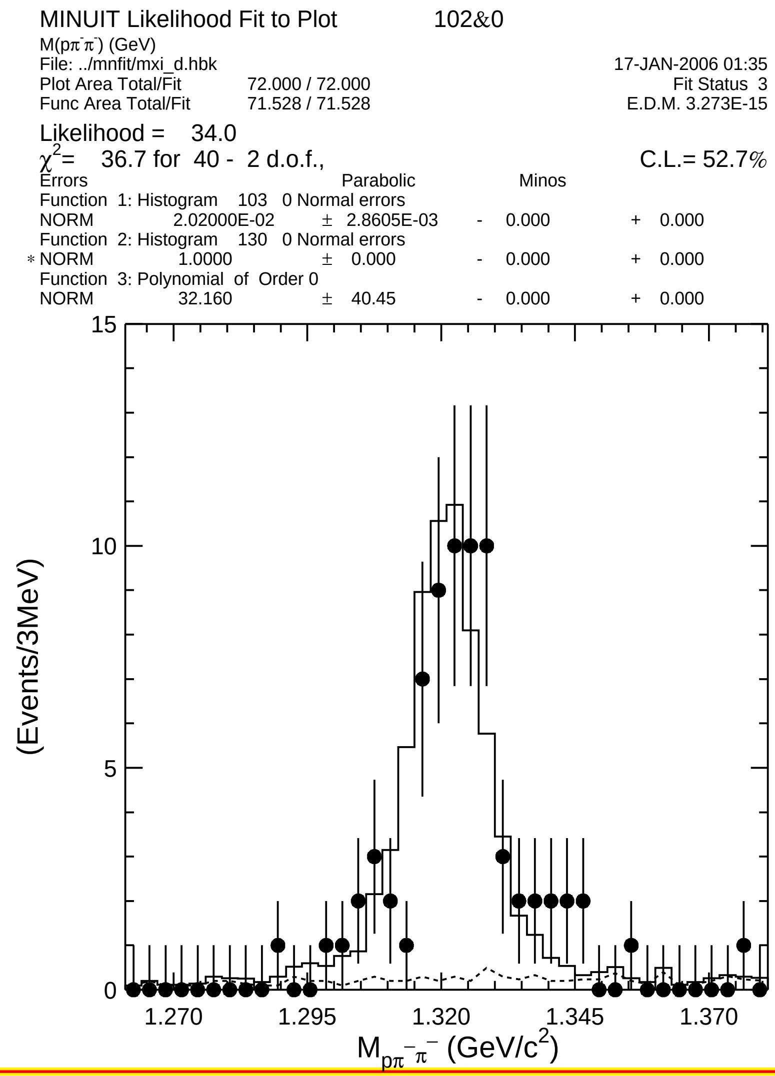


Figure VIII

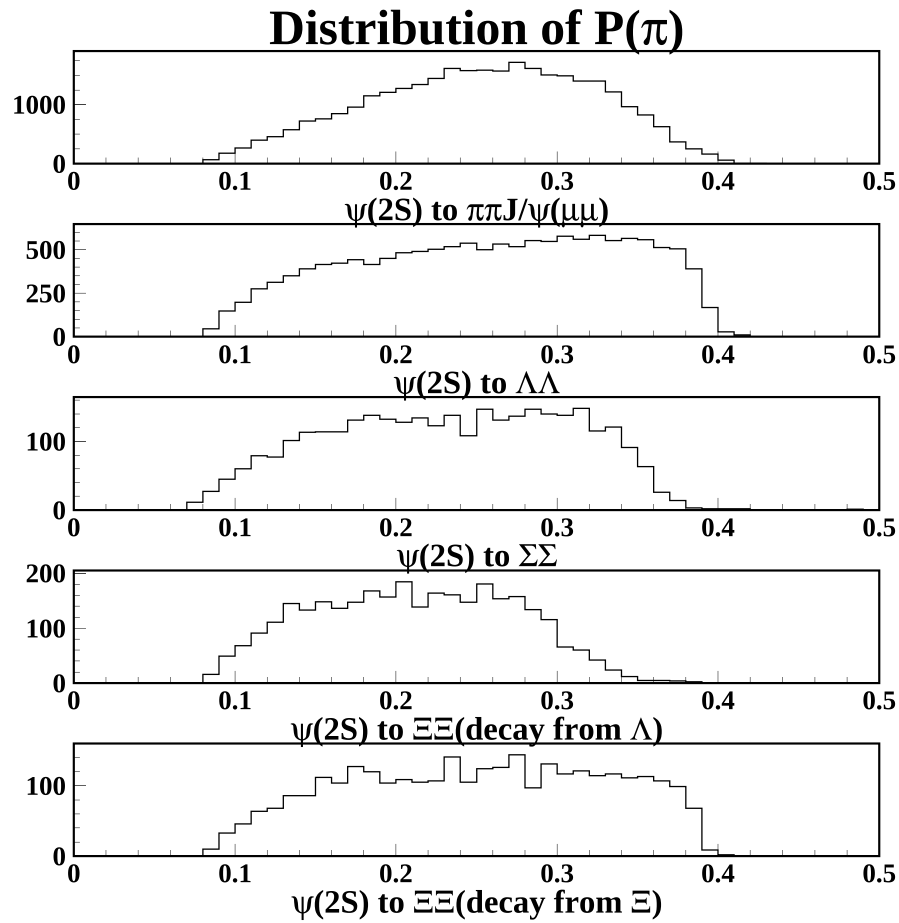
Mass spectrum of Ξ^- and fitting [Back.]





MDC Tracking I

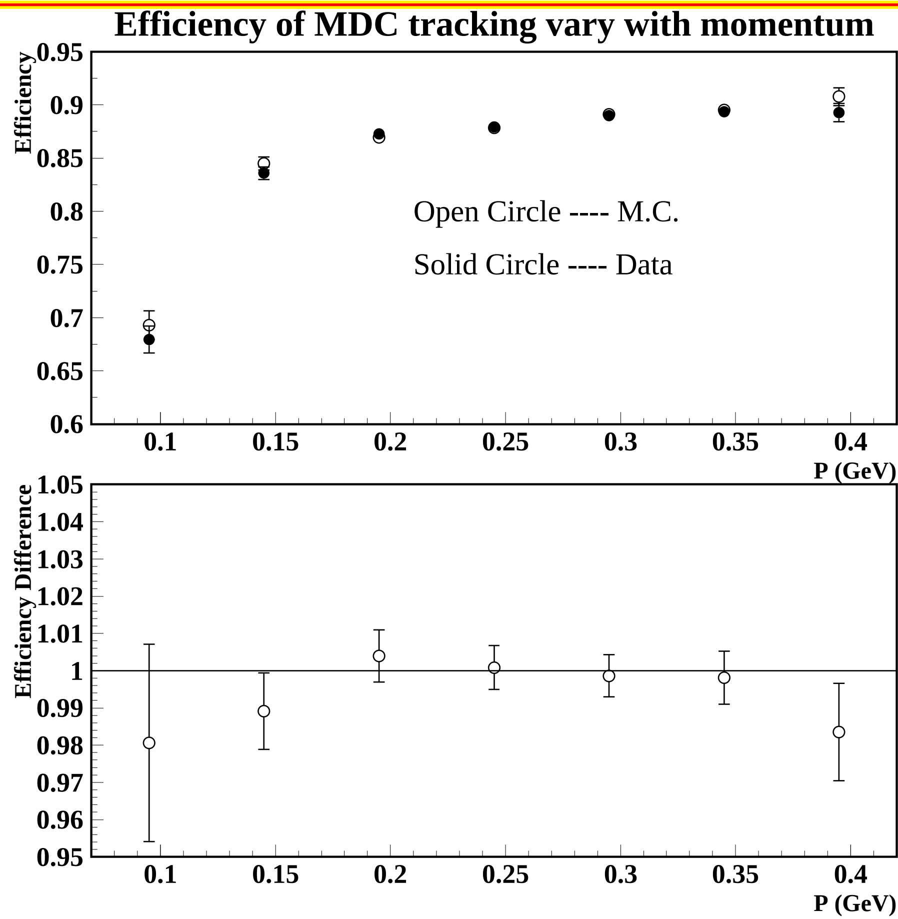
In the final states of the four channels, there are 2 kind of charged tracks p and π. The momenta distribution of ps are extensive, the systematic error of MDC tracking for p is taken $2\%/track$ from the previously analysis; while, the momenta of πs are all no more than 0.42GeV, here we choose $\psi' \to \pi^+\pi^- J/\psi(J/\psi \to \mu^+\mu^-)$ as the reference channel to study the MDC tracking for low-momentum-π.



MDC Tracking II

Event Selection of $\psi' \to \pi^+\pi^- J/\psi \to \pi^+\pi^-\mu^+\mu^-$

- 3 or 4 well reconstruted charged tracks;
- PID: 2 charged tracks with $P > 1.25GeV$ are assumed to be μs, $muid1 + muid2 \geq 3$, when $muid1 + muid2 = 3$, the $E_{deposit} < 0.2GeV$;
  1 charged track with $P < 0.45GeV$ is assumed to be π, $prob_\pi > 0.01$, $prob_\pi > prob_p, prob_\pi > prob_K$;
- $|M_{recoiling}(\pi\pi_{miss}) - M_{J/\psi}| < 0.072GeV$; (From M.C. simulation, the resolution of $M_{J/\psi}$ is about 24MeV)
- $1 - C\ fit$ for $J/\psi \to \mu^+\mu^-$ with $prob(\chi^2, 1) > 0.01$.



From the right figure, the systematic error of MDC tracking for low-momentum-π is about 1% by weighting average.[Back.]

Sys. Err. of Kinematic Fit

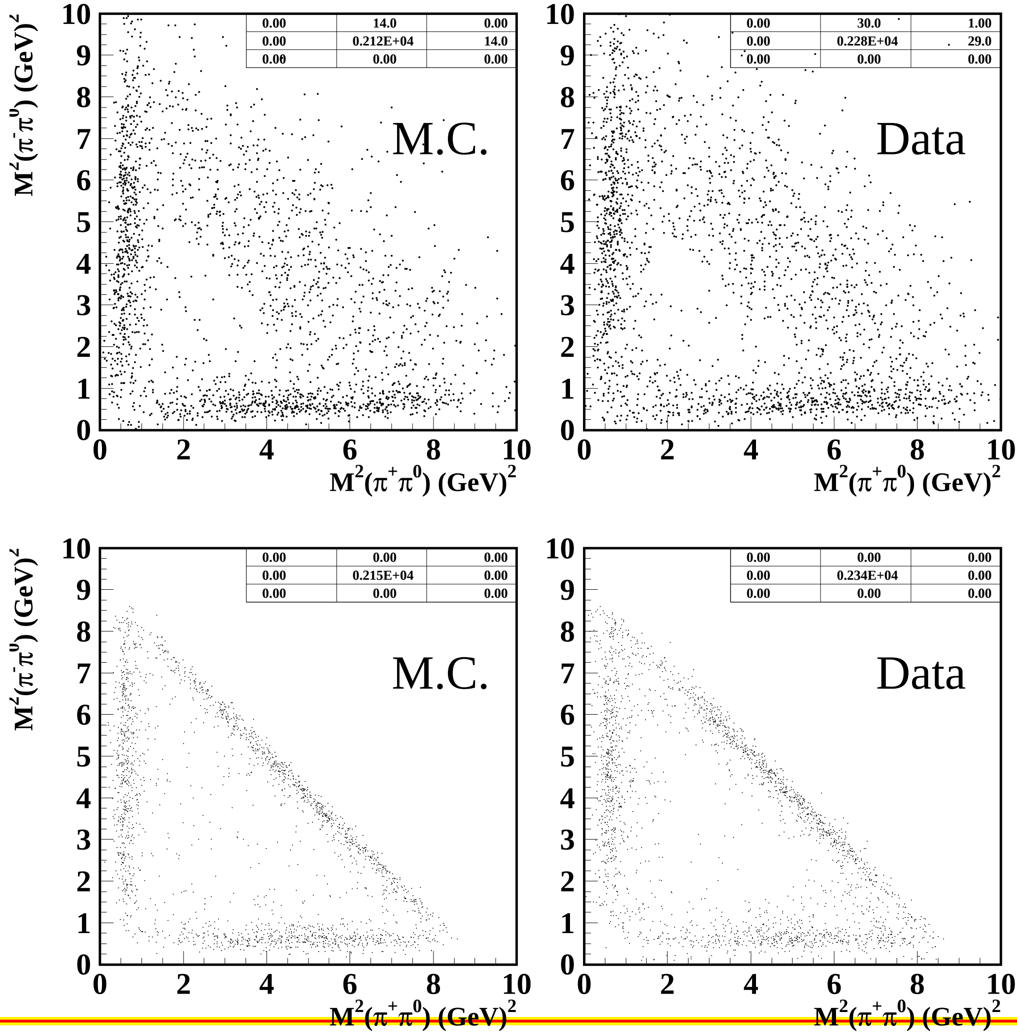
We choose $\psi' \to \pi^+\pi^- J/\psi (J/\psi \to \rho\pi)$ as the reference channel to study the systematic error of kinematic fit for 4-prong, 2-γ process.[Back.]
Event selection:

- 4 well reconstructed charged tracks;
- 2 good γs;
- PID: each particle should satisfy $prob_\pi > prob_p$ and $prob_\pi > prob_K$;
- Resonance mass: $|M_{recoiling}(\pi^+\pi^-) - M_{J/\psi}| < 0.035GeV$, $M_{\pi^+\pi^-\pi^0} > 2.7GeV$;
- $P_{miss} > 0.2GeV$ and $U_{miss} < 0.3GeV$;
- $P_{\pi 1} + P_{\pi 2} > 1.45GeV$, $P_{\pi 1}$ and $P_{\pi 2}$ are the momenta of π decay from J/ψ;
- $\theta_{\gamma\gamma} > 5^o$.

Then we get the efficiency of M.C. is $(86.13 \pm 0.77)\%$ and the efficiency of Data is $(80.71 \pm 0.87)\%$, the difference is $(6.29 \pm 1.31)\%$, 7.6% is taken. [Figure]

The Dalitz plot of 3π

The upper two figures are without kinematic fit, the lower two are after kinematic fit: [Back.]



Sys. Err. of Λ vertex finding

We choose $J/\psi \to \Lambda\bar{\Lambda} \to \pi^+\pi^- p\bar{p}$ as the reference channel to study the systematic error of Λ vertex finding algorithm:
Event selection:

- 4 well reconstructed charged tracks;
- PID: to π, $prob_\pi > prob_p$ and $prob_\pi > prob_K$; to p, $prob_p > prob_\pi$ and $prob_p > prob_K$;
- The $\bar{p}\ \pi^+$ should pass the scondary vertex finding algorithm;
- $3.02GeV < E_{\Lambda\bar{\Lambda}} < 3.2GeV$;
- $|M_{p\pi^-} - M_\Lambda| < 0.008GeV$, $|M_{\bar{p}\pi^+} - M_\Lambda| < 0.008GeV$, (From M.C. the resolution of M_Λ is about 2.8MeV);

Then we get the efficiency of M.C. is $(89.50 \pm 0.24)\%$ and the efficiency of Data is $(89.28 \pm 0.29)\%$, the difference is $(0.25 \pm 0.42)\%$, 0.7% is taken.
[Back.]

Sys. Err. of Λ decay length

We choose $J/\psi \to \Lambda\bar{\Lambda} \to \pi^+\pi^- p\bar{p}$ as the reference channel to study the systematic error of Λ decay length:

Event selection:

- 4 well reconstructed charged tracks;
- PID: to π, $prob_\pi > prob_p$ and $prob_\pi > prob_K$; to p, $prob_p > prob_\pi$ and $prob_p > prob_K$;
- 2 pair of $p\pi$s should pass the secondary vertex finding algorithm;
- $3.02GeV < E_{\Lambda\bar{\Lambda}} < 3.2GeV$;
- $|M_{p\pi^-} - M_\Lambda| > 0.008GeV$, $|M_{\bar{p}\pi^+} - M_\Lambda| > 0.008GeV$, (From M.C. the resolution of M_Λ is about 2.8MeV);

Then we get the efficiency of M.C. is $(95.38 \pm 0.21)\%$ and the efficiency of Data is $(95.99 \pm 0.24)\%$, the difference is $(0.65 \pm 0.33)\%$, 1.0% is taken.

[Back.]

The Difference of M.C. Efficiency

The efficiency of GCALOR versus that of FLUKA, the statistics of each M.C. sample is 100k:[Back.]

Table 2: *M.C. Efficiency(%)*

M.C Sample	$p\bar{p}$	$\Lambda\bar{\Lambda}$	$\Sigma^0\bar{\Sigma}^0$	$\Xi^-\bar{\Xi}^+$
GCALOR	34.48 ± 0.15	17.20 ± 0.14	3.44 ± 0.07	3.83 ± 0.07
FLUKA	35.23 ± 0.16	17.13 ± 0.14	3.44 ± 0.07	3.78 ± 0.06
Difference	2.18 ± 0.65	0.41 ± 1.15	0.00 ± 2.88	1.31 ± 2.39

Since the statistics of M.C. sample can be as big as we like, the statistic error can be ignored, here, only the mean values of the efficiency difference are taken into account.

Error Estimation of α Value

When the M.C. generated, the α value is a parameter, its value will affect the detection efficiency of M.C.

To $\psi' \to p\bar{p}$, the α value has been measured by this analysis, we change its value by 1σ, the efficiency of M.C. changes about 2.0%;

To $\psi' \to \Lambda\bar{\Lambda}, \Sigma^0\bar{\Sigma}^0, \Xi^-\bar{\Xi}^+$, the current statistics of these channels is not enough to measure the α value directly, and there is no available value by theroy prediction or measurement before. The values used in this analysis are 0.5, we also generate M.C. samples with the α value equal to 0 and 1, the bigger difference of $|\epsilon_{\alpha-current} - \epsilon_{\alpha=0}|$ and $|\epsilon_{\alpha-current} - \epsilon_{\alpha=1}|$ are taken to be the systematic errors of α value for these three channels, there 6.5%, 7.6%, 6.8%, respectively.

[Back.]

The main backgrounds for $\psi' \to p\bar{p}$[Back.]

Channel	$N_{in\ 14M\ \psi'}$	$N_{Gen.}$	$N_{Obs.}$	$N_{Norm.}$
Bhabha($\vert cos(\theta)\vert < 0.85$)	3,545,630	3,545,630	0	0
$\psi' \to e^+e^-$($\vert cos(\theta)\vert < 0.85$)	84,560	84,560	0	0
Dimu($\vert cos(\theta)\vert < 0.85$)	110,881	221,762	2	1.0
$\psi' \to \mu^+\mu^-$($\vert cos(\theta)\vert < 0.85$)	81,760	163,520	0	0
$\psi' \to \pi^+\pi^-$	1,120	11,200	0	0
$\psi' \to K^+K^-$	1,400	14,000	0	0
$\psi' \to \gamma\chi_{C0} \to \gamma p\bar{p}$	326	3,260	2	0.2
$\psi' \to \gamma\chi_{C0} \to \gamma\pi^+\pi^-$	8,825	88,250	7	0.7
$\psi' \to \gamma\chi_{C0} \to \gamma K^+K^-$	8,380	83,800	57	5.7
$\psi' \to \gamma\chi_{C1} \to \gamma p\bar{p}$	67	670	20	2.0
$\psi' \to \gamma\chi_{C2} \to \gamma p\bar{p}$	58	580	107	10.7
$\psi' \to \gamma\chi_{C2} \to \gamma\pi^+\pi^-$	2,115	21,150	4	0.4
$\psi' \to \gamma\chi_{C2} \to \gamma K^+K^-$	1,300	13,000	22	2.2
$\psi' \to \pi^0 p\bar{p}$	1,940	20,000	13	1.3
$\psi' \to \pi^0\pi^0 J/\psi \to \pi^0\pi^0\mu^+\mu^-$	151,064	151,064	13	13
Total				37.2

Table B-I

The main backgrounds for $\psi' \to \Lambda\bar{\Lambda}$ [Back.]

Channel	$N_{in\ 14M\ \psi'}$	$N_{Gen.}$	$N_{Obs.}$	$N_{Norm.}$
$\psi' \to \pi^+\pi^- p\bar{p}$	11,200	112,000	2	0.2
$\psi' \to \pi^+\pi^- J/\psi \to \pi^+\pi^- p\bar{p}$	9,409	94,090	50	5.0
$\psi' \to \Sigma^0\bar{\Sigma}^0$	1,504	20,416	151	11.2
$\psi' \to \gamma\chi_{c0} \to \gamma\Lambda\bar{\Lambda}$	232	2,320	0	0
$\psi' \to \gamma\chi_{c0} \to \gamma\gamma J/\psi \to \gamma\gamma\Lambda\bar{\Lambda}$	87	870	0	0
$\psi' \to \gamma\chi_{c1} \to \gamma\Lambda\bar{\Lambda}$	125	1,250	2	0.2
$\psi' \to \gamma\chi_{c1} \to \gamma\gamma J/\psi \to \gamma\gamma\Lambda\bar{\Lambda}$	2,230	22,300	0	0
$\psi' \to \gamma\chi_{c2} \to \gamma\Lambda\bar{\Lambda}$	125	1,250	33	3.3
$\psi' \to \gamma\chi_{c2} \to \gamma\gamma J/\psi \to \gamma\gamma\Lambda\bar{\Lambda}$	1,086	10,860	0	0
$\psi' \to \Lambda\bar{\Sigma}^0 + c.c.[\star]$	187.5+187.5	20,000+20,000	1,290	12.1
Total				32.0

Table C-I

The main backgrounds for $\psi' \to \Sigma^0\bar{\Sigma}^0$ [Back.]

Channel	$N_{in\ 14M\ \psi'}$	$N_{Gen.}$	$N_{Obs.}$	$N_{Norm.}$
$\psi' \to \Lambda\bar{\Lambda}$	4,872	50,000	17	1.6
$\psi' \to \gamma\chi_{C0} \to \gamma\Lambda\bar{\Lambda}$	232	2,320	2	0.2
$\psi' \to \gamma\chi_{C1} \to \gamma\Lambda\bar{\Lambda}$	125	1,250	11	1.1
$\psi' \to \gamma\chi_{C2} \to \gamma\Lambda\bar{\Lambda}$	125	1,250	4	0.4
$\psi' \to \Xi^0\bar{\Xi}^0 \to \pi^0\pi^0\Lambda\bar{\Lambda}$	1,572	20,416	45	3.5
$\psi' \to \Lambda\bar{\Sigma}^0 + c.c.$	187.5+187.5	20,000+20,000	136	1.3
$\psi' \to \Sigma^0\bar{\Xi}^0 + c.c.$	150.4+150.4	10,000+10,000	246	3.7
$\psi' \to \gamma\chi_{C0} \to \gamma\Sigma^0\bar{\Sigma}^0 \to \gamma\gamma\gamma\Lambda\bar{\Lambda}$	232	2,320	26	2.6
$\psi' \to \gamma\chi_{C1} \to \gamma\Sigma^0\bar{\Sigma}^0 \to \gamma\gamma\gamma\Lambda\bar{\Lambda}$	125	1,250	9	0.9
$\psi' \to \gamma\chi_{C2} \to \gamma\Sigma^0\bar{\Sigma}^0 \to \gamma\gamma\gamma\Lambda\bar{\Lambda}$	125	1,250	12	1.2
Total				16.5

Table D-I

The main backgrounds for $\psi' \to \Xi^-\bar{\Xi}^+$ [Back.]

Channel	$N_{in\ 14M\ \psi'}$	$N_{Gen.}$	$N_{Obs.}$	$N_{Norm.}$
$\psi' \to \pi^+\pi^- J/\psi \to \pi^+\pi^-\Lambda\bar{\Lambda}$	3,679	36,790	72	7.2
$\psi' \to \pi^+\pi^- J/\psi \to \pi^+\pi^-\Sigma^0\bar{\Sigma}^0 \to \pi^+\pi^-\Lambda\bar{\Lambda}\gamma\gamma$	2,537	25,370	0	0
$\psi' \to \Sigma(1385)^+\Sigma(1\bar{3}85)^+ \to \Lambda\bar{\Lambda}\pi^+\pi^- + c.c.$	2×547.2	2×15,000	29	1.1
$\psi' \to \pi^+\pi^- J/\psi \to \pi^+\pi^-\Lambda\bar{\Sigma}^0 \to \pi^+\pi^-\Lambda\bar{\Lambda}\gamma + c.c.$	2×181.5	2×1,815	0	0
Total				8.3

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