Determination of Total Number of J/ψ from 4-prong Data

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Contents

1 Introduction

At BESII,About 50 million J/ψ collected from November 1999 to May 2001 has been reconstructed by Data Production Group.It is about 5000 runs(Run13691-16835 and Run17209-19149), but only good runs are used by calling the code **jpsi_runstatus.f** [1]

It is important to determine the total number of J/ψ events, since many physics analyses are based on it,especially for precise measurement branching ratio of J/ψ decays.

To determine the total number of J/ψ we used the new ψ' data smaple collected at the same time with J/ψ to analyse the channel $\psi' \to \pi^+\pi^-\psi$.

2 Method

The traditional method to determine the total number of J/ψ is to use the fromula[2]:

$$N_{J/\psi} = (R^o + 1) \times \Sigma_{i=1}^{6} \frac{N^i \times \epsilon_i^{scan}}{\epsilon_i^{trig}} - N_{QED}^{BB}$$

where,
R^o is the ratio of 0-prong events to all the charged events of J/ψ;N^i(i=1,2,3,4,5,$\geq$6) is the number of i-prong events; ϵ_i^{scan} is the manual scan efficenicy of i-prong events; ϵ_i^{trig} is the trigger efficenicy of i-prong events; N_{QCD}^{BB} is the number of Bhabha events from electromagnetic scattering.But,in this method,it is difficult to estimate the background from Bhabha scattering and to determine the ratio R^o because there are many fake photon in the neutral events.

In [3], a new method based on the above method was introduced.Only 4-prong events was allowd for determing the total number of J/ψ.So the formula above becomes:

$$N_{J/\psi} = \frac{N_{4prg} \times (1 - R_{bg})}{\epsilon_{4prg}^{trig} \times R_{4prg}}$$

where,
N_{4prg} and ϵ_{4prg}^{trig} have the same meaning as above, R_{bg} is the ratio of backgroud to 4-prong events; and R_{4prg} is the ratio of 4-prong events to the total number of J/ψ,which was got through the channel $\psi' \to \pi^+\pi^- J/\psi$.

3 Step

Using the new method to determine the total number of J/ψ,we can divided it into four steps:

- **Calculating the ratio of 4-prong events number to the total J/ψ($\mathbf{R}_{4prg}$);**
- **Counting the total 4-prong events(N_{4prg});**
- **Estimating the ratio of backgroud to 4-prong events($\mathbf{R}_{bg}$);**
- **Determing the 4-prong trigger efficiency(ϵ_{4prg}^{trig}).**

3.1 Calculating the ratio of 4-prong events numbers to the total J/ψ

In order to get R_{4prg},the channel$\psi' \rightarrow \pi^+\pi^- J/\psi$ was analysed. The line shape of J/ψ in M_{recoil}^{any} and M_{recoil}^{4prg} distribution is used to fit out the number of $N_{J/\psi}^{any}$ and $N_{J/\psi}^{4prg}$,respectively.Then we can get $R_{4prg} = \frac{N_{J/\psi}^{4prg}}{N_{J/\psi}^{any}}$. The ψ' data sample Run16853-Run17018 is used for the ratio of first data set ,and Run19363-Run19466 for the second data set of J/ψ.

- **Event Selection for $\psi' \rightarrow \pi^+\pi^- J/\psi$**
  - **All the charged tracks are from MDC**
  - **Nchrg $\geq$ 2**
  - **Mfit=2 or Mfit=-19**
  - **Pxyπ >0.06Gev**
  - $|x|$ **≤10cm;**$|y|$ **≤10cm;**$|z|$ **≤20cm**
  - $\sqrt{\chi^2_{\pi^+} + \chi^2_{\pi^-}}$ **<4.5(** $\chi^2_{\pi^\pm} = \frac{(DE/dx)_{meas} - (DE/dx)_{exp}}{\sigma}$)
  - **P**$_{\pi^\pm}$ **<0.5Gev**
  - $|cos\theta_\pi|$ **<0.8**
  - $|cos\theta_{\pi^\pm}|$ **<0.95**

- **At least two charged π with low momentum was selected**

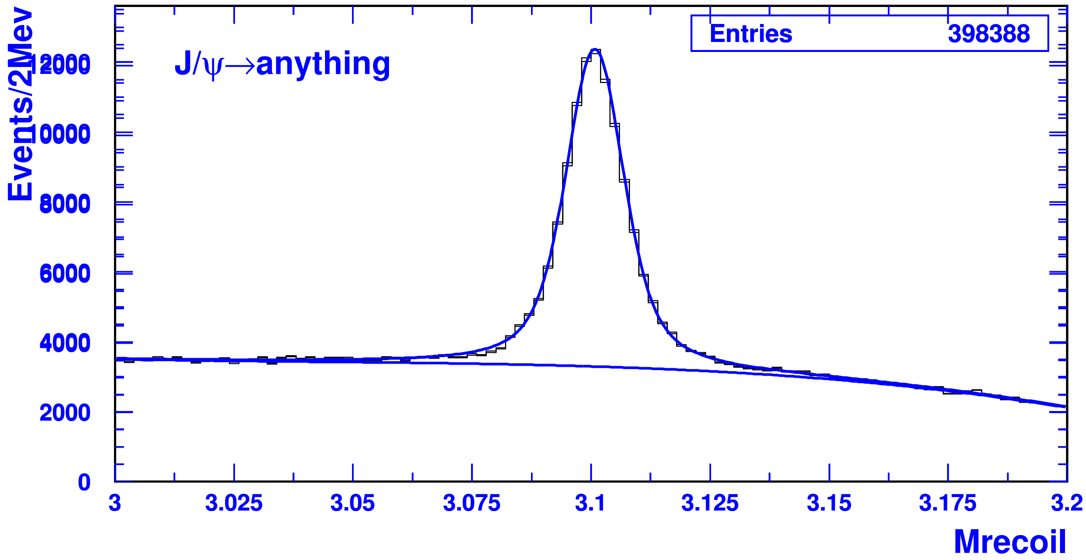
- **Recoiling Mass Spectrum Fitting**
  The sum of three polynomial background and a Breit-Wigner curve convolved a Gaussian resolution function is used to fit the mass distributions recoiling against $\pi^+\pi^-$(shown in Fig.1,2,3 and 4). Theoreticaly,the mass resolution should be stablized ,which obtained from Monto Carlo.But,in fact,the mass resolution fitted out from Monto Carlo is greater than the width Γ of DATA.So the mass resolution is set free just as the width when we fit the mass spectrum.The fitting results and R_{4prg} is shown in Table 1 and Table 2.

Table 1: M_{recoil}^{any} fitting results of inclusive events

	The first data set	The second data set
Run#	16853–17018	19363–19466
$J/\psi \to$anything		
N_{any}^{sel}	398387	701645
Area	0.21303±0.00243	0.21222±0.00184
N_{any}^{obj}	84868.38±968.08	148903.10±1291.03
$J/\psi \to$4-prongs		
N_{4prg}^{sel}	94243	166106
Area	0.21389±0.00492	0.21113±0.00376
N_{any}^{obj}	20157.64±463.68	35069.96±622.90
Ratio of 4-prongs to anything events		
R_{4prg}	0.2375±0.0061	0.2355±0.0046

3.2 Counting the total 4-prong events

- To counting the total 4-prong events,three loose cuts were used:
  - $|x| \leq$**10cm;**$|y| \leq$**10cm;**$|z| \leq$**20cm**
  - **Mfit=2 or -19**
  - ΣQ_i**=0**
  - **Only good runs are used(Runstatus 1 or 2)!!!**
- Statistical Results of 4-prong events

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==============================================’==================================
I Summary Of BWFIT Results’ I
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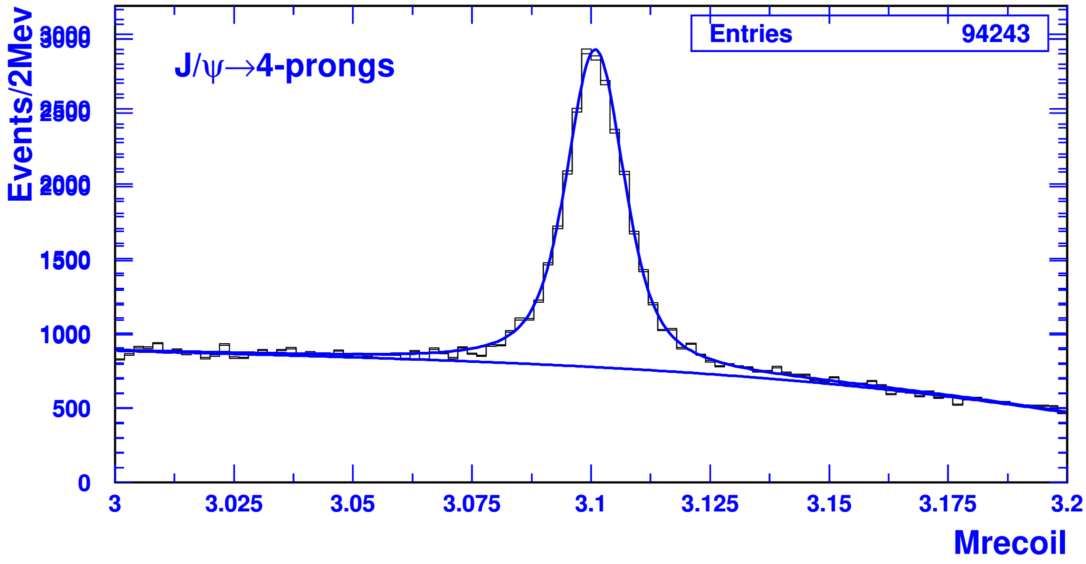
Histogram ID=   100  AdapQuad Breit-Wigner Fit using  100 Points
Fit Parameters:Npoly=   4 Nbw=   1 Namp=   0 Range=      3.000 To      3.200
Hist. Chisq =       96.76 for   7 params &  92 DF.
Chisquare Probability =  34.68%. Mean and S.D. for pulls:    -.0028     .9837
Likelihood ratio and probability                :     59.964        99.61%
Final Value of Log Likelihood                   :   -681449.68
Error Correspond to a Function Chage            :      .50
Phase Space limits for tails corrections        :       .280GEV     2.817GEV
Breit-Wigner efficiency correction factors      :      .976
Include Breit-Wigner tails outside fit region :        .004
Efficiency-corrected events in fit region      :   398387.[average eff. :1.000]
---THE FITTED VALUES AND ERRORS OF THE PARAMETERS:---
    LEG1Value : -.18581    Error(Cov,-/+):     .315E-02  .000E+00  .000E+00
    LEG2Value : -.10307    Error(Cov,-/+):     .595E-02  .000E+00  .000E+00
    LEG3Value : -.35326E-01Error(Cov,-/+):     .488E-02  .000E+00  .000E+00
    AREAValue :  .21303    Error(Cov,-/+):     .243E-02  .000E+00  .000E+00
    RESLValue :  .42221E-02Error(Cov,-/+):     .164E-03  .000E+00  .000E+00
    GAMAValue :  .75861E-02Error(Cov,-/+):     .409E-03  .000E+00  .000E+00
    MASSValue :  3.1008    Error(Cov,-/+):     .415E-04  .000E+00  .000E+00
```

Figure 1: M_{recoil}^{any} fitting for $J/\psi \to$ anything of the first data set

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==============================================’==================================
I                      Summary Of BWFIT Results’                                 I
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Histogram ID=   100  AdapQuad Breit-Wigner Fit using  100 Points
Fit Parameters:Npoly=   4 Nbw=   1 Namp=   0 Range=     3.000 To     3.200
Hist. Chisq =      84.03 for   7 params &  92 DF.
Chisquare Probability =  71.10%. Mean and S.D. for pulls:    -.0014     .9167
Likelihood ratio and probability              :     75.350       89.63%
Final Value of Log Likelihood                 :   -161275.11
Error Correspond to a Function Chage          :      .50
Phase Space limits for tails corrections      :       .280GEV     2.817GEV
Breit-Wigner efficiency correction factors    :      .973
Include Breit-Wigner tails outside fit region :        .004
Efficiency-corrected events in fit region     :    94243.[average eff. :1.000]
---THE FITTED VALUES AND ERRORS OF THE PARAMETERS:---
    LEG1Value : -.25880    Error(Cov,-/+):    .651E-02  .000E+00  .000E+00
    LEG2Value : -.89644E-01Error(Cov,-/+):    .122E-01  .000E+00  .000E+00
    LEG3Value : -.21958E-01Error(Cov,-/+):    .970E-02  .000E+00  .000E+00
    AREAValue :  .21389    Error(Cov,-/+):    .492E-02  .000E+00  .000E+00
    RESLValue :  .38783E-02Error(Cov,-/+):    .338E-03  .000E+00  .000E+00
    GAMAValue :  .84764E-02Error(Cov,-/+):    .790E-03  .000E+00  .000E+00
    MASSValue :  3.1009    Error(Cov,-/+):    .845E-04  .000E+00  .000E+00
```
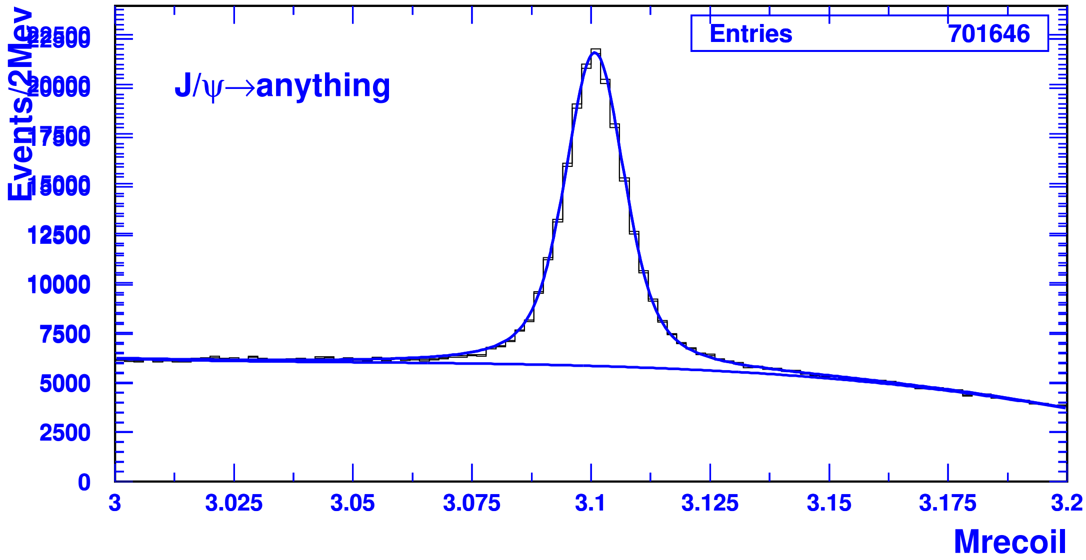

Figure 2: M^{4prg}_{recoil} fitting results for $J/\psi \to$ 4-prongs of the first data set

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==============================================='=================================
I                         Summary Of BWFIT Results'                             I
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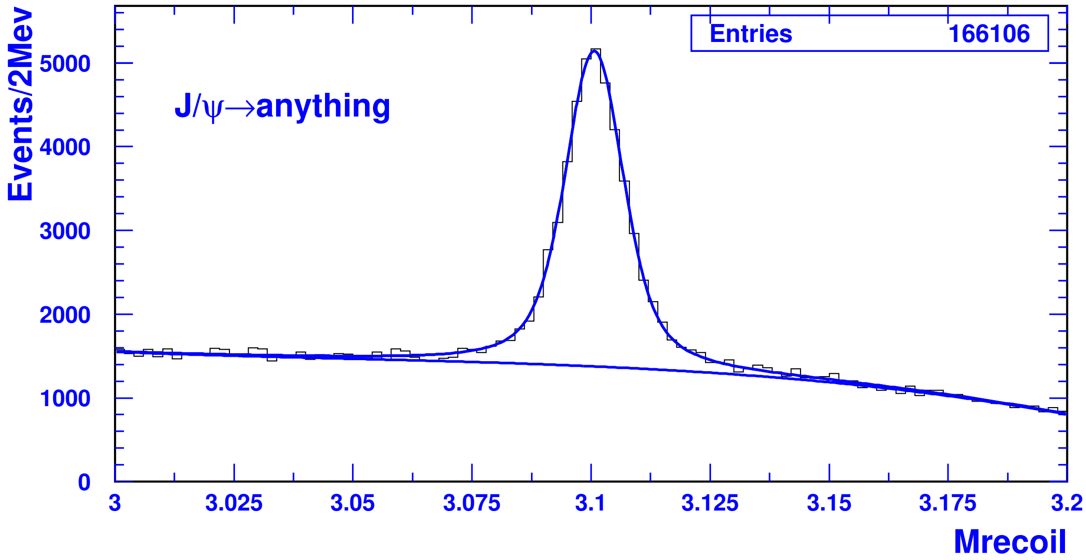
Histogram ID=   100  AdapQuad Breit-Wigner Fit using  100 Points
Fit Parameters:Npoly=    4 Nbw=    1 Namp=    0 Range=      3.000 To      3.200
Hist. Chisq =      122.70 for    7 params &  92 DF.
Chisquare Probability =   1.79%. Mean and S.D. for pulls:    -.0038    1.1077
Likelihood ratio and probability              :      57.929        99.79%
Final Value of Log Likelihood                 :  -1200096.74
Error Correspond to a Function Chage          :       .50
Phase Space limits for tails corrections      :        .280GEV     2.817GEV
Breit-Wigner efficiency correction factors    :       .977
Include Breit-Wigner tails outside fit region :         .004
Efficiency-corrected events in fit region     :   701645.[average eff. :1.000]
---THE FITTED VALUES AND ERRORS OF THE PARAMETERS:---
    LEG1Value : -.18483    Error(Cov,-/+):    .234E-02  .000E+00  .000E+00
    LEG2Value : -.10797    Error(Cov,-/+):    .449E-02  .000E+00  .000E+00
    LEG3Value : -.42480E-01Error(Cov,-/+):    .367E-02  .000E+00  .000E+00
    AREAValue :  .21222    Error(Cov,-/+):    .184E-02  .000E+00  .000E+00
    RESLValue :  .44406E-02Error(Cov,-/+):    .121E-03  .000E+00  .000E+00
    GAMAValue :  .73201E-02Error(Cov,-/+):    .309E-03  .000E+00  .000E+00
    MASSValue :  3.1008    Error(Cov,-/+):    .315E-04  .000E+00  .000E+00
```

Figure 3: M^{4prg}_{recoil} fitting results for $J/\psi \to$ anything of the second data set

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=============================================='=================================
I                      Summary Of BWFIT Results'                                I
=============================================='=================================
Histogram ID=   100  AdapQuad Breit-Wigner Fit using  100 Points
Fit Parameters:Npoly=    4 Nbw=    1 Namp=    0 Range=      3.000 To      3.200
Hist. Chisq =      122.35 for    7 params &  92 DF.
Chisquare Probability =   1.89%. Mean and S.D. for pulls:    -.0019    1.1061
Likelihood ratio and probability             :    106.776        13.91%
Final Value of Log Likelihood                :   -284650.84
Error Correspond to a Function Chage         :      .50
Phase Space limits for tails corrections     :       .280GEV     2.817GEV
Breit-Wigner efficiency correction factors   :      .977
Include Breit-Wigner tails outside fit region :       .004
Efficiency-corrected events in fit region    :   166106.[average eff. :1.000]
---THE FITTED VALUES AND ERRORS OF THE PARAMETERS:---
    LEG1Value : -.24703     Error(Cov,-/+):    .492E-02  .000E+00  .000E+00
    LEG2Value : -.10288     Error(Cov,-/+):    .918E-02  .000E+00  .000E+00
    LEG3Value : -.38338E-01Error(Cov,-/+):    .729E-02  .000E+00  .000E+00
    AREAValue :  .21113     Error(Cov,-/+):    .376E-02  .000E+00  .000E+00
    RESLValue :  .43486E-02Error(Cov,-/+):    .245E-03  .000E+00  .000E+00
    GAMAValue :  .72831E-02Error(Cov,-/+):    .623E-03  .000E+00  .000E+00
    MASSValue :  3.1007     Error(Cov,-/+):    .632E-04  .000E+00  .000E+00
```

Figure 4: M^{4prg}_{recoil} fitting for $J/\psi \to$ 4-prongs of the second data set

Table 2: The statistical results of 4-prong events

J/ψ data set	Run#	M.C. version	$N_{4prg}(\times 10^6)$	Total $(\times 10^6)$
The First	13691–15797	021	3.82	5.92
	15798–16242	022	0.89	
	16243–16835	023	1.21	
The second	17029–17361	024	0.42	6.40
	17362–17725	025	1.20	
	17726–18086	026	1.14	
	18123–18200	027	0.28	
	18201–18600	028	1.34	
	18601–19000	029	1.44	
	19001–19149	030	0.58	

3.3 Estimating the ratio of backgroud to 4-prong events

In the J/ψ data sample,there are also lots of background except the good event for physics analysis.Some backgroud events are identified as good 4-prong events when we selected the 4-prong events.The backgroud mainly come from cosmic rays,beam-gas and non-resonance events.Those background can be estimated by 3.0Gev data sample,which collected for studying background.To estimate the ratio,we selected 4-prong events from it used the above selection cuts.As a results, we regard the average events a Run from it as the bacground in the 4-prong events selected from J/ψ data sample for every Run,then we can estimate the ratio of backgroud to 4-prong events.

Table 3: Results of estimating backgrond

	The first data set	The second data set
Run#	15443-15489	18087-18122
$R_{bg}(\%)$	1.64	1.02

3.4 Determing trigger efficiency of 4-prong events

The data used for calculating the trigger efficency is Run13931-13939.A special trigger table has been used for collecting these data.
Dr. Li De have calculated hadrons' trigger efficiency[4].I only do it for 4-prong events data sample. According to Ref[4],three channels were used for determing the hadrons' trigger efficiceny:

- **Charged channel:**$\mathbf{N_{tof} \geq 1, N_{vc} \geq 1, N_{trk} \geq 1}$ **and** $\mathbf{E_{tot.l}}$

- **Charged-2 channel:**$\mathbf{N}_{tof}$ **≥2,**$\mathbf{N}_{vc}$ **≥1 and** $\mathbf{N}_{trk}$ **≥2**
- **Neutral channel:**$\mathbf{R}_{radial}$ **and** $\mathbf{E}_{tot.h}$

To get the trigger efficiency of a trigger condition, the information of the subdectector which the trigger conditions came from should not be used.

$\epsilon N_{tof} \geq 1$	99.929
$\epsilon N_{tof} \geq 2$	99.856
$\epsilon N_{vc} \geq 1$	99.929
$\epsilon N_{trk} \geq 1$	1.000
$\epsilon N_{trk} \geq 2$	99.929
Radial	44.592
Etot-l(20)	99.972
Etot-h(55)	85.023
ϵ_{4prg}^{trig}	99.912

Table 4: Trigger efficiency of every trigger conditions

4 Error Analyses

The statistical error comes from N_{4prg} can be ignored,and and the systermatic error mainly comes from:

4.1 Inclusive Process

It mainly comes from the charged pions selection criteria with change.And the errors are shown in Table 5.

4.2 Fitting Method

The fitting of the mass distributions recoiling $\pi^+\pi^-$ leads to 2.57% and 1.94%,respectively,for the two data sets of J/ψ,including the statistical error from $\mathrm{N}_{any}^{recoil}$ and $\mathrm{N}_{4prg}^{recoil}$.

4.3 Estimating background

We regard the one standard dviation times confidence level(99.9%) as the error from the uncertainty of estimating backgroud.

4.4 Trigger efficiency

The trigger efficiency is approximately 100%,and We regard the difference of $\epsilon_{hadrons}$[4] and ϵ_{4prg}^{trig} as the systematic error,it is about 0.3%.

4.5 The difference between the J/ψ at rest and the flying J/ψ from ψ'

Theoretically,the J/ψ from $\psi' \to \pi^+\pi^- J/\psi$ have momentum and it will have a Lorentz boost when it decays.That is the difference with the rest J/ψ directly comes from e^+ e^- collidering.It is difficult to estimate the difference between them by theoretical calculation.
In order to estimate the difference,we used the Monto Carlo generator[5] to monitor $\psi' \to \pi^+\pi^- J/\psi$.As a result,the difference between them is about 4%.

4.6 4-prong events selection criteria

Table 5: Systematic error fors for $N_{J/\psi}$

	The first data set	The second data set
Error sources	Realtive Error	
$\|cos\theta\pi^+\pi^-\| < 0.95 \to 0.98$	0.58	0.71
$\|P_{\pi\pm}\| < 0.5 \to 0.45Gev$	0.1	0.12
$\|Pxy_{\pi\pm}\| > 0.06 \to 0.08Gev$	0.3	0.37
$\|\sqrt{\chi^2_{\pi^+} + \chi^2_{\pi^-}}\| < 4.5 \to 4.0$	0.36	0.19
$\|\cos\theta_{\pi\pm}\| < 0.8 \to 0.85$	0.67	0.35
Fitting Method	2.57	1.94
Trigger efficiency	0.29	0.29
Flying J/ψ	4.04	4.04
No Mfit cuts	0.45	2.03
Vertex cuts	0.98	1.46
Estimation of Backgroud	0.22	0.45
Total	5.03	5.24

5 Results

5.1 Results for the first data set

$$N_{J/\psi} = (24.55 \pm 1.23) \times 10^6$$

5.2 Results for the second data set

$$N_{J/\psi} = (26.92 \pm 1.41) \times 10^6$$

Table 6: The statistical results of 4-prong events

J/ψ data set	Run#	M.C. version	$N_{J/\psi}(\times 10^6)$	Total $(\times 10^6)$
The First	13691–15797	021	15.85	24.55
	15798–16242	022	3.70	
	16243–16835	023	5.00	
The second	17029–17361	024	1.76	26.92
	17362–17725	025	5.03	
	17726–18086	026	4.79	
	18123–18200	027	1.18	
	18201–18600	028	5.65	
	18601–19000	029	6.06	
	19001–19149	030	2.45	

6 Aknowledgements

We would like to thank J/ψ group members for their useful suggestions. In particular we are greateful to Prof. Z.G Zhao,Prof. X.Y. Shen, Prof. F. Harris,prof. D.H. Zhang,Prof. Z.P. Mao,Dr. Z.J. Guo,Dr. Y.K. Heng,Dr. X.B. Ji,etc for their valuable remarks and discussions. At last,thanks Dr. H.J Lu,Dr. H.P Peng for their help.

References

[1] jpsi_runstatus.f, written by Shen Xiaoyan.

[2] Yu Zhong Qiang et al.,*"Estimation of the Fourth data sets of J/ψ"*,BES internal reports(1993).

[3] Ma Aimin, Ph.D thesis(1995).

[4] Li De,BES Monthly Meeting,April 13,2000.

[5] Zhang Dahua, Monto Carlo Generator:*Ugent102*.