Determine the Total Number of J/ψ from $J/\psi \to \mu^+\mu^-$

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1 Data and Method

1.1 J/ψ data and QED BG data

The analyzed data are from run13700 to run16835. Totally about 3000 runs of J/ψ data and 47 runs of QED data.

1.2 Method

The following formular is to calculate the J/ψ number. Because the two processes $J/\psi \to \mu^+\mu^-$ and $e^+e^- \to \mu^+\mu^-$ have the same final states, the second one will be inevitably selected in dimuon candidates. These QED B.G. must be removed.

$$N_{J/\psi} = \frac{N_{\mu\mu} - N_{ee\to\mu\mu}}{\varepsilon_{trg} \times \varepsilon_{\mu\mu 1} \times BR} \tag{1}$$

$N_{\mu\mu}$: number of dimuon cand.
$N_{ee\to\mu\mu}$: number of B.G. from $ee \to \mu\mu$
ε_{trg}: trigger eff.
$\varepsilon_{\mu\mu 1}$: detection and selection eff. from $J/\psi \to \mu^+\mu^-$
BR: Branching Ratio of $J/\psi \to \mu^+\mu^-$

2 Selection of Dimuon

We use the following criteria to select the dimuon events, and the figure 1-4 are about these criteria.

a) Exactly two oppositely charged tracks are found and they meet the vertex, polar angel and momentum limit: $r < 1.5cm, |z| < 15cm$, $cos\theta < 0.6$ and $1.0 < P < 2.1(GeV/c)$.

b) Back-to-back: $||\Delta\phi| - 180| < 2$

c) Time of flight:$|T - T_{exp}| < 1.0(ns), |T_1 - T_2| < 1.3(ns)$

d) The two tracks pass the muon ID: At least one good hit at muon counter and the muon status greater than one.

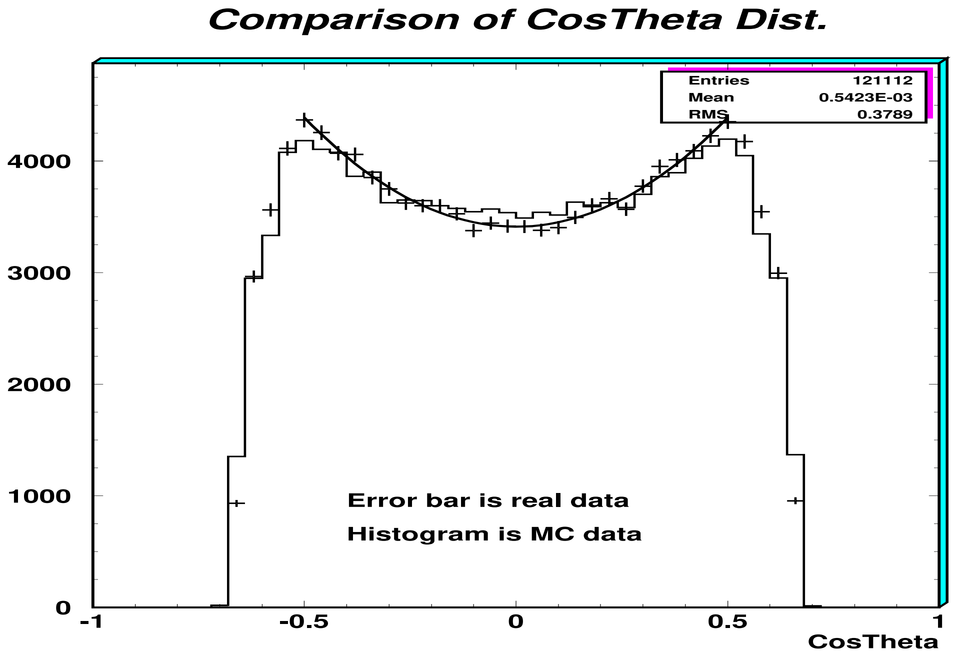

Figure 1:

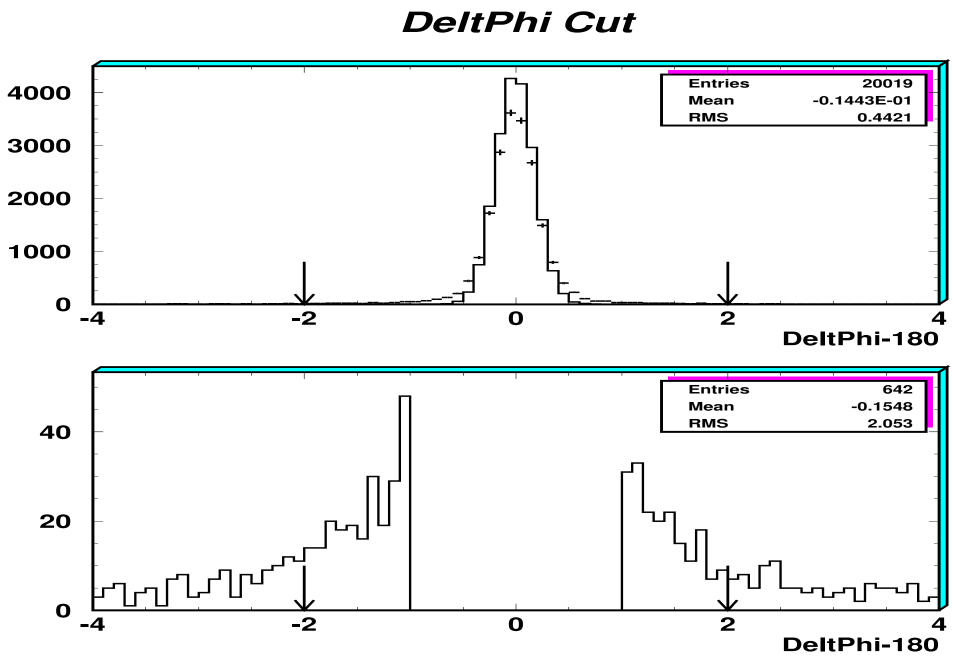

Figure 2:

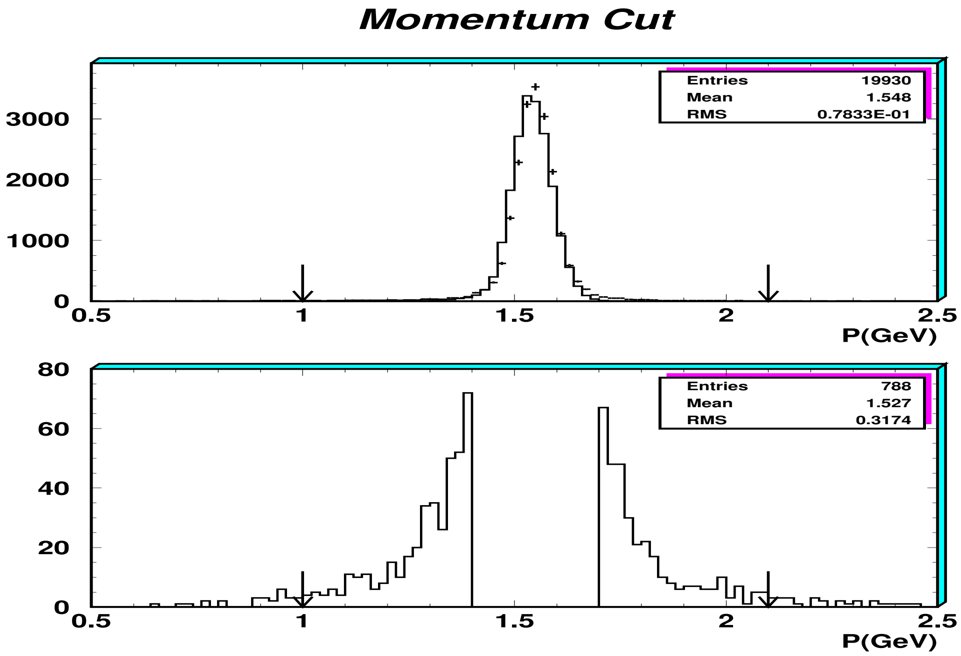

Figure 3:

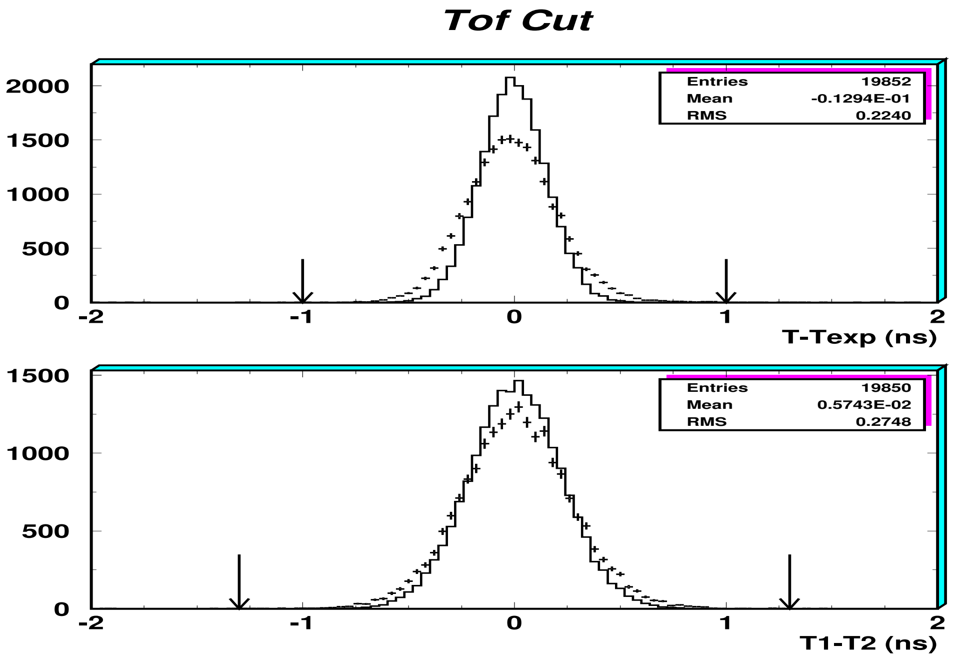

Figure 4:

3 QED B.G. Estimate

3.1 Methods

One method is using data at 3.0 GeV, totally 47 runs.

$$N_{ee\to\mu\mu} = \frac{N^{3.0}_{ee\to\mu\mu} \times L \times \sigma}{L^{3.0} \times \sigma^{3.0}} \tag{2}$$

$N_{ee\to\mu\mu}$ or $N^{3.0}_{ee\to\mu\mu}$: number of selected dimuon from $ee \to \mu\mu$
L or $L^{3.0}$: integral luminosity
σ or $\sigma^{3.0}$: cross section of $ee \to \mu\mu$
The other method is using theoretical cross section of $ee \to \mu\mu$

$$N_{ee\to\mu\mu} = L \times \sigma \times \varepsilon_{\mu\mu 2} \tag{3}$$

where $\sigma = 11.46(nb)$ by our MC.

3.2 Luminosity from $e^+e^- \to \gamma\gamma(\gamma)$

Both methods of B.G. estimate need the integral luminosity. The QED process of $e^+e^- \to \gamma\gamma(\gamma)$ has no interference from J/ψ's decay, so the integral luminosity is calculated by it:

$$L = \frac{N_{\gamma\gamma}}{\varepsilon_{\gamma\gamma} \times \sigma_{\gamma\gamma}} \tag{4}$$

Here the calculation refers to R group work, Dr. Huang G.S. and Wang Z.Y. The syst. error is less than 4

Event Selection:
a) No charged track and neutral track number is 2 or 3.
b) Avoid ribbon region in BSC.
c) Polar Angle: $cos\theta < 0.7$
d) Deposit energy in BSC: $1.1 < E < 1.9(GeV)$
e)Back-to-Back: $||\Delta\phi| - 180| < 1.5$
The following table lists the integral luminosity for J/ψ data and QED data.

Table 1: Integral Luminosity

Data	$\sigma(nb)$	$\varepsilon(\%)$	LM(nb^{-1})
J/ψ	249.7	2.10	7333 ± 293
3.0GeV	264.9	2.14	177 ± 9

3.3 Number of B.G.

At last by method one the B.G. events' number is (28.5 ± 2.9)K, which is deduced from 733 ± 59 of $ee \to \mu\mu$ events selected in 3.0 GeV data. By method two 33.9 ± 2.2 K B.G. is obtained from $L = 7333 \pm 59$, $\sigma = 11.46(nb)$ and $\varepsilon_{\mu\mu 2} = 40.4\%$. The two results are consistent within two s.d.

4 Result and error

4.1 No. of J/ψ

By the above criteria, we select 667 thousand dimuons, where the B.G. is 28.5 thousand(refers to method one), the detection and selection efficience is 44.7%, the trigger eff. of dimuon events is 99.6% according the work of Dr Li De, and so the total number of J/ψ is (23.8 ± 1.4)M.

4.2 Error: 6%

Firstly the error from selection criteria are small and they are obtained by varying one s.d. of each relative varible and comparing the results. Secondly the QED B.G. is about 5% in the total dimuon candidates and so the error from B.G. is small too. Also the MID from hadronic decays in the dimuon candidates is negligible. Only 0.004% with over one photon inside the dimuon sample.

The biggest error comes from efficiency by MC. It is found that the $cos\theta$ distribution of MC is a little inconsistent with data. Theoretically the distribution should be $1+cos^2\theta$. But the data is deeper and the MC is higher in the middle(see figure 1). After many checks the reason is found that the MDC hit efficiency(including hardware and software, i.e. the ratio the hitted layer number to be used in tracking to the total layer number 40) varies with $cos\theta$, which can be seen in the last figure. Comparing the difference the error from MC is estimated as 5%.

Table 2: Error Analysis

Source	ϕ	TOF	Muon ID	B. G.	BR	ϵ	Total
Error(%)	$^{+0.2}_{-0.3}$	$^{+0.1}_{-0.2}$	$^{+0.5}_{-1.0}$	±0.4	±3.2	±5.0	±6.0

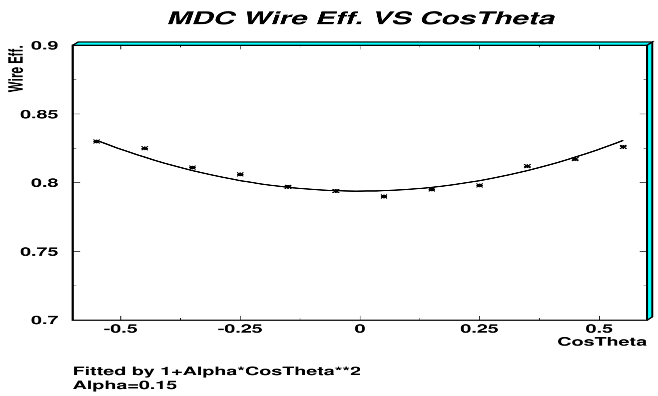

Figure 5:

At last I want to give my sincere thanks for many meaningful discussion to Prof. Lu J.G., Prof. Shen X.Y., Prof. Zhang C.C., Prof. Zhang D.H., Prof. Liu H.M., Prof. Mao Z.P., Dr. Huang G.S., Dr. Wang Z.Y., etc.