Appendix A

Monte Carlo Simulation Study of the Process \( e^+e^- \rightarrow J/\psi \gamma \)

The radiative return process \( e^+e^- \rightarrow J/\psi \gamma \) has been generated using a generator from PYTHIA [36]. The generator includes the Born level amplitude only (zeroth order approximation). The production angle of \( \gamma \) was limited to the range 10° to 160° in the lab frame and the energy of \( \gamma \) was required to be greater than 1.0 GeV. The production cross section in the above acceptance is \( \sigma(e^+e^- \rightarrow J/\psi \gamma) = 6.40 \pm 0.07 \text{ pb} \). Only \( J/\psi \rightarrow \mu^+\mu^- \) decays have been simulated because the channel \( J/\psi \rightarrow e^+e^- \) from this reaction is substantially suppressed by the hadronic event selection requirements (Chapter 5.2). The simulated data set contains 20 \( \times 10^3 \) events. Typical features of the simulated events are shown in Fig. A.1. The distributions are shown after applying the hadronic selection cuts, except for the \( N_{ch} > 4 \) requirement.

The process has two-body kinematics. The \( p_{J/\psi}^* \) distribution exhibits a monochromatic peak at 4.8 GeV/c, smeared by the momentum resolution. \( N_{ch} = 2 \) events constitute about 90\% of the total sample, the remaining 10\% have higher charged track multiplicity \( N_{ch} = 3, 4 \) due to photon conversions in the detector material. These events are the backgrounds to the prompt \( J/\psi \) sample, contributing with a cross section of about 0.6 pb. This background is eliminated if the \( N_{ch} > 4 \) cut is used. The production angle distribution (Fig A.1(d)) shows characteristic strong forward/backward peaks (\( \sim \sin^{-2}\theta^* \)), partially reduced by acceptance losses for the small/large \( \theta \).

A comparison of \( p_{J/\psi}^* \) distributions for the data and Monte Carlo (MC) simulation for \( N_{ch} = 4 \) is shown in Fig. A.2. The MC distribution is normalized to the data luminosity. For the data distribution, the background subtraction was made using side-bands of the \( J/\psi \)
invariant mass distribution. Good agreement is observed, although the MC distribution has a smaller tail towards low momentum. This could be due to imperfect treatment of the radiative smearing of the initial state energy.

Figure A.1: (a) Charged track multiplicity, (b) ratio between second and zeroth Fox-Wolfram moments, (c) $J/\psi$ momentum in CM. (d) cosine of the production angle $\theta^*$ between beam direction and $J/\psi$ three momentum in CM without acceptance correction.
Figure A.2: filled circle histogram shows the $J/\psi$ momentum in CM predicted from $e^+e^- \rightarrow J/\psi(\mu\mu)\gamma$ (MC) and empty circle histogram is from data requiring charged track multiplicity $= 4$. 