I. DESCRIPTION OF THE BEPCII AND THE BESIII DETECTOR

The BESIII detector [1] records symmetric $e^+e^-$ collisions provided by the BEPCII storage ring [2], which operates with a peak luminosity of $1 \times 10^{33} \text{cm}^{-2}\text{s}^{-1}$ in the center-of-mass energy range from 2.0 to 4.7 GeV. BESIII has collected large data samples in this energy region [3]. The cylindrical core of the BESIII detector covers 93% of the full solid angle and consists of a helium-based multilayer drift chamber (MDC), a plastic scintillator time-of-flight system (TOF), and a CsI(Tl) electromagnetic calorimeter (EMC), which are all enclosed in a superconducting solenoidal magnet providing a 1.0 T (0.9 T in 2012) magnetic field. The solenoid is supported by an octagonal flux-return yoke with resistive plate counter muon identification modules interleaved with steel. The charged-particle momentum resolution at 1 GeV/$c$ is 0.5%, and the $dE/dx$ resolution is 6% for electrons from Bhabha scattering. The EMC measures photon energies with a resolution of 2.5% (5%) at 1 GeV in the barrel (end cap) region. The time resolution in the TOF barrel region is 68 ps, while that in the end cap region is 110 ps. The end cap TOF system was upgraded in 2015 using multi-gap resistive plate chamber technology, providing a time resolution of 60 ps [4].

II. INCLUSIVE MC DESCRIPTION

Simulated data samples produced with a GEANT4-based [1] Monte Carlo (MC) package, which includes the geometric description of the BESIII detector and the detector response, are used to determine detection efficiencies and to estimate backgrounds. The simulation models the beam energy spread and initial state radiation (ISR) in the $e^+e^-$ annihilations with the generator KKMC [2]. (Pick any of the following, depending on the data sets analyzed.)

- **the J/$\psi$ data set**
  The inclusive MC sample includes both the production of the $J/\psi$ resonance and the continuum processes incorporated in KKMC [2].

- **the $\psi$(3686) data set**
  The inclusive MC sample includes the production of the $\psi$(3686) resonance, the ISR production of the $J/\psi$, and the continuum processes incorporated in KKMC [2].

- **the $\psi$(3770) data set**
  The inclusive MC sample includes the production of $D\bar{D}$ pairs (including quantum coherence for the neutral $D$ channels), the non-$D\bar{D}$ decays of the $\psi$(3770), the ISR production of the $J/\psi$ and $\psi$(3686) states, and the continuum processes incorporated in KKMC [2].

- **the data set above 3.9 GeV**
  The inclusive MC sample includes the production of open charm processes, the ISR production of vector charmonium(-like) states, and the continuum processes incorporated in KKMC [2].

The known decay modes are modelled with EVTGEN [3] using branching fractions taken from the Particle Data Group [4], and the remaining unknown charmonium decays are modelled with LUNDCHARM [5]. Final state radiation (FSR) from charged final state particles is incorporated using the PHOTOS package [6].


[4] cite the reference given in the pdglive:  
http://pdglive.lbl.gov/ParticleGroup.action?init=0&node=BXXX040.


III. RECOMMENDED REFERENCES FOR POPULAR ITEMS

• The BESIII physics book

• The BESIII white paper

• The BOSS framework
  D. M. Asner et al., Int. J. Mod. Phys. A 24, S1 (2009);  
  J. Zhang et al., Radiat. Detect. Technol. Methods 2, 20 (2018). (cite the last one only if using BOSS 7.0.3 or later)

• PYTHIA

• PHOKHARA
  below list generic references for PHOKHARA:
  H. Czyz, J. H. Kuhn and A. Wapienik, Phys. Rev. D 77, 114005 (2008);  
for reference to any specific PHOKHARA version, check out the website http://ific.uv.es/~rodrigo/phokhara/

• Babayaga

when using BABAYAGA@NLO, cite the two references below:

when using BABAYAGA3.5, however, cite the below two references:

• Novosibirsk function


• ARGUS function


• KeysPdf: the shape of the kernel-estimate


IV. RECOMMENDED DESCRIPTION OF TRACK-LEVEL EVENT SELECTION

Choose the descriptions relevant to your analysis:

• Good charged track

  – Charged tracks detected in the MDC are required to be within a polar angle (θ) range of |cosθ| < 0.93, where θ is defined with respect to the z-axis.
For charged tracks not originating from \( K_0^* \) or \( \Lambda \) decays, the distance of closest approach to the interaction point (IP) must be less than 10 cm along the z-axis, \(|V_z|\), and less than 1 cm in the transverse plane, \(|V_{xy}|\).

**Good photon selection**

- Photon candidates are identified using showers in the EMC. The deposited energy of each shower must be more than 25 MeV in the barrel region (\(|\cos \theta| < 0.80\)) and more than 50 MeV in the end cap region (\(0.86 < |\cos \theta| < 0.92\)).
- To exclude showers that originate from charged tracks, the angle between the position of each shower in the EMC and the closest extrapolated charged track must be greater than 10 degrees.
- To suppress electronic noise and showers unrelated to the event, the difference between the EMC time and the event start time is required to be within (0, 700) ns.

**Particle identification**

- **PID for hadrons**
  
  Particle identification (PID) for charged tracks combines measurements of the energy deposited in the MDC \((dE/dx)\) and the flight time in the TOF to form likelihoods \(\mathcal{L}(h)\) \((h = p, K, \pi)\) for each hadron \(h\) hypothesis. Tracks are identified as protons when the the proton hypothesis has the greatest likelihood \((\mathcal{L}(p) > \mathcal{L}(K)\) and \(\mathcal{L}(p) > \mathcal{L}(\pi))\), while charged kaons and pions are identified by comparing the likelihoods for the kaon and pion hypotheses, \(\mathcal{L}(K) > \mathcal{L}(\pi)\) and \(\mathcal{L}(\pi) > \mathcal{L}(K)\), respectively.

- **PID for positron and hadrons in charm semi-leptonic decays**
  
  Positron PID uses the measured information in the MDC, TOF and EMC. The combined likelihoods \((\mathcal{L}')\) under the positron, pion, and kaon hypotheses are obtained. Positron candidates are required to satisfy \(\mathcal{L}'(e) > 0.001\) and \(\mathcal{L}'(e)/(\mathcal{L}'(e) + \mathcal{L}'(\pi) + \mathcal{L}'(K)) > 0.8\). To reduce background from hadrons and
muons, the positron candidate is further required to have a deposited energy in the EMC greater than 0.8 times its momentum obtained in the MDC.

- **Secondary vertex for $K^0_S$**

$K^0_S$ candidates are reconstructed from two oppositely charged tracks satisfying $|V_z| < 20$ cm. The two charged tracks are assigned as $\pi^+\pi^-$ without imposing further PID criteria. They are constrained to originate from a common vertex and are required to have an invariant mass within $|M_{\pi^+\pi^-} - m_{K^0_S}| < 12$ MeV/$c^2$, where $m_{K^0_S}$ is the $K^0_S$ nominal mass [4]. The decay length of the $K^0_S$ candidate is required to be greater than twice the vertex resolution away from the IP.