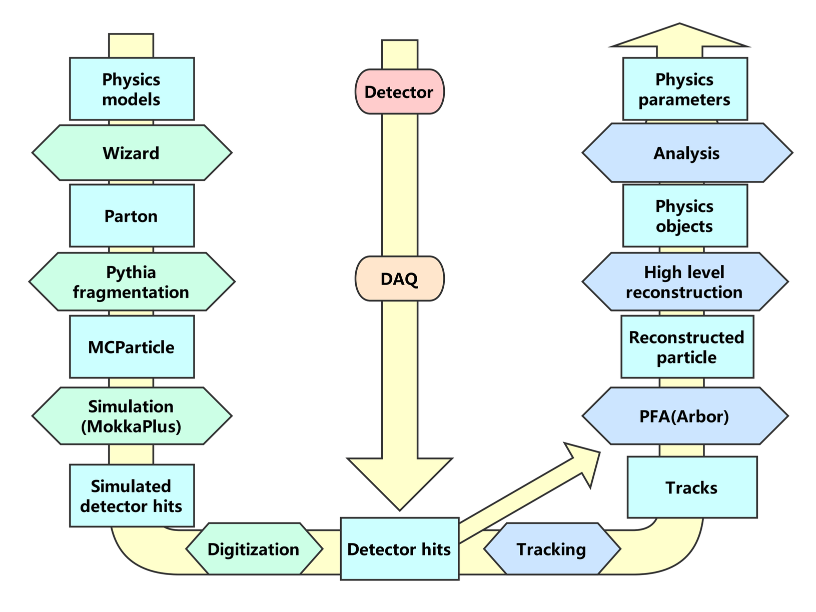
Reconstruction of Physics Objects at the Circular Electron Positron Collider with Arbor

Pei-Zhu Lai[1], Bo Liu[2], Man-Qi Ruan[2], Chia-Ming Kuo[1], for the CEPC Collaboration
[1]Depart. of Physics & Center for high energy & high field physics, National Central University, Chung-li, Taiwan
[2]Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China

INTRODUCTION

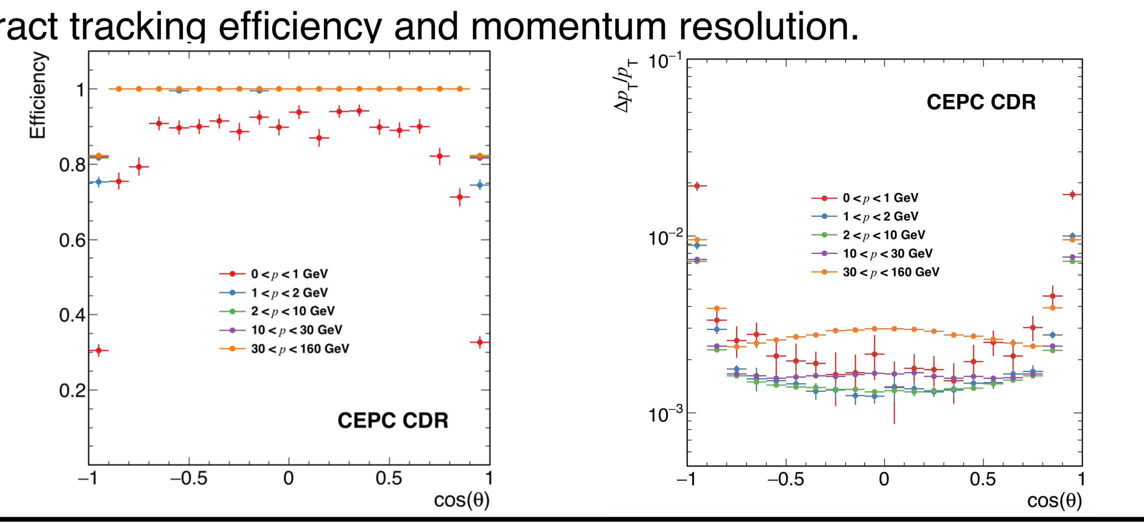
After the Higgs discovery precise measurements become vital for the experimental particle physics. A powerful Higgs factory, the Circular electron-positron Collider (CEPC), is proposed. Adequate detector design and reconstruction algorithm are fundamental to this project. The Particle Flow oriented detector design is proposed to the CEPC and a Particle Flow algorithm, Arbor, is optimized accordingly. The performance of physics object reconstruction with Arbor algorithm and how this combination fulfills the physics requirement of CEPC will be presented.

EVENT SIMULATION



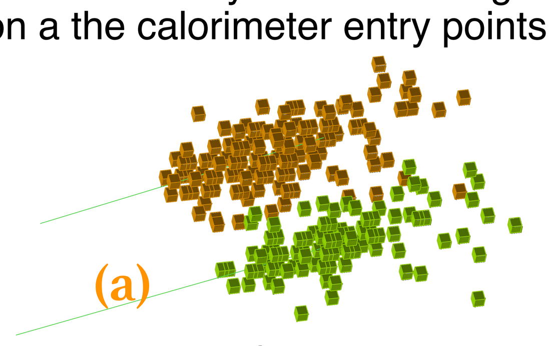
TRACK RECONSTRUCTION

The CEPC baseline tracker consists of a silicon tracking system and a barrel TPC. A single muon particle sample and an $e^+e^-\to Z\to\tau^+\tau^-$ sample are used to extract tracking efficiency and momentum resolution.

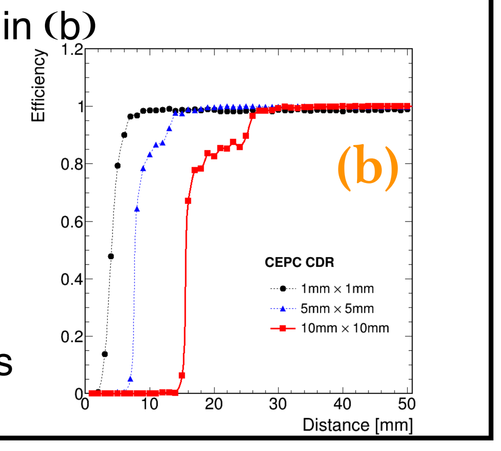


CLUSTER RECONSTRUCTION

The average efficiency of 50% for reconstructing two photons as two separate clusters from a 30 GeV π^0 decay with similar energy. The secondary step structures in the efficiency curves reflect the finite granularity of the calorimeter. The efficiencies for successfully reconstructing two photon clusters as the function of their separation a the calorimeter entry points are shown in (b)

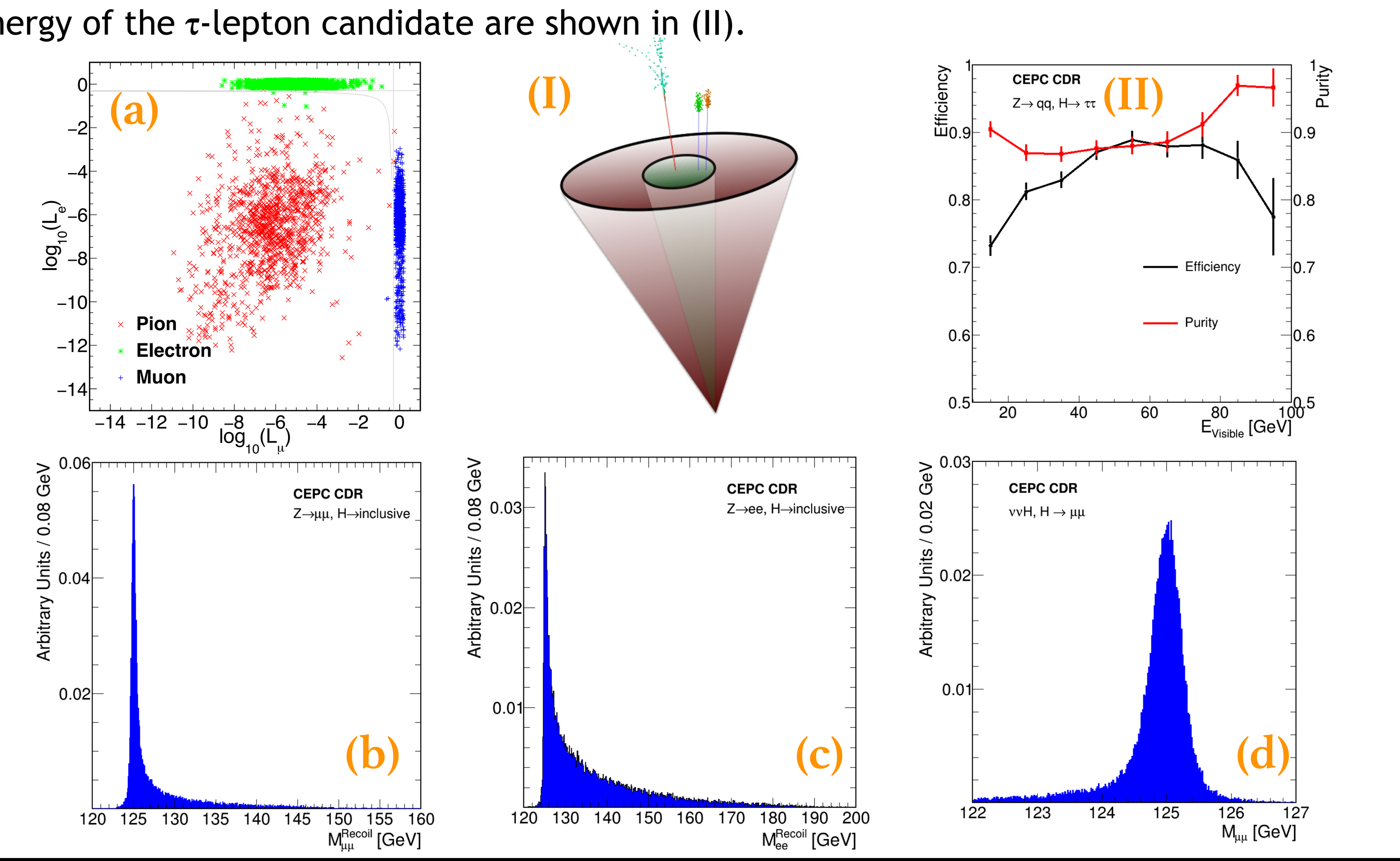


(a) is a demonstration of the reconstructed clusters from two closely spaced photons from a π^0 decays.



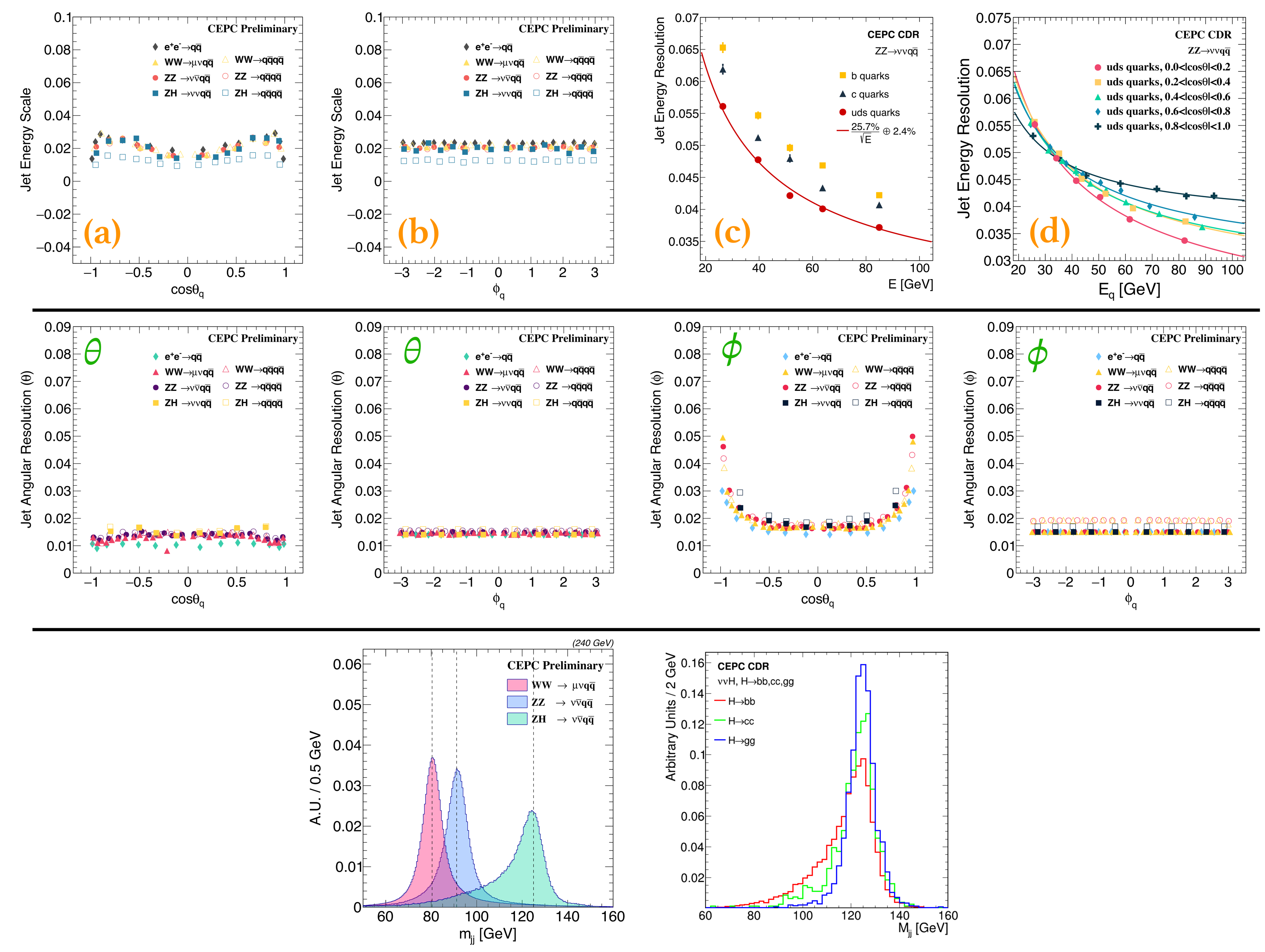
LEPTONS

A lepton identification algorithm, LICH, has been developed and implemented in ARBOR. (a) compares the two-dimensional distributions of L_e and L_μ expected from single electrons, muons and charged poions, shoring clear separations among these particles. For leptons above 2 GeV, and identifications efficiency better than 99.5% and a mis-identification probability from hadrons smaller than 1% can be achieved. (b-c) shows the reconstructed recoil mass distributions of the $Z\to\mu^+\mu^-$ and $Z\to e^+e^-$ decays from the $e^+e^-\to ZH$ process., and (d) is the dimuon invariant mass distribution of $H\to\mu^+\mu^-$ angina from $e^+e^-\to ZH$. The sharp peak at the Higgs boson mass demonstrates the excellent lepton energy/momentum and angular resolutions. (I) is a graphic representation of the τ-lepton identification. The total energy in an annular cone or radius between 0.12-0.32 radians is required to be less than 8% of τ-lepton candidate energy. The efficiency and the purity as functions of the visible energy of the τ-lepton candidate are shown in (II).

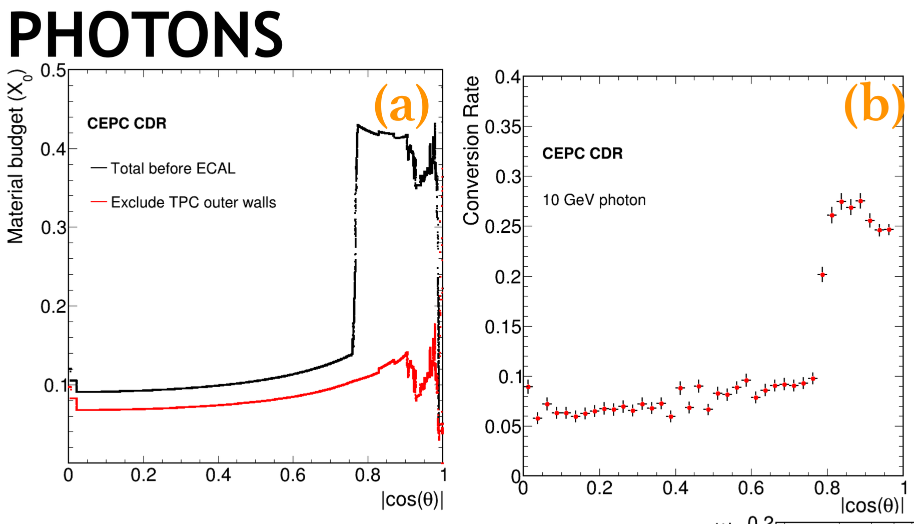


JETS

(a) shows jet energy scale(JES) between the reconstructed jets and MC particle jets for different polar angles derived from the simulated two jets or four jets final state events. The JES is close to 2% and the variation is < 1%, and keeps homogeneous in the Φ direction which is shown in (b). The jet energy resolution (JER) is shown in (c) as a function of jet energy for different jet flavors. For light jets, the resolution ranges from 6% at 20 GeV to 3.6% at 90 GeV. The resolutions for heavy-flavor are poorer as expected because of neutrinos in their decays. The JERs for light jets in different range of cosθ is shown in (d). The bottom column shows the JAR between the reconstructed jets and MC particle for different polar angles derived from the simulated two jets or four jets final state events. JAR is close to 1.5% and the variation is < 1%, and it is independent of the Φ direction. Meanwhile the JAR difference of 7 processes is < 1%. These excellent energy and angular resolution bring us the well separation of W, Z, and Higgs dijet invariant mass.

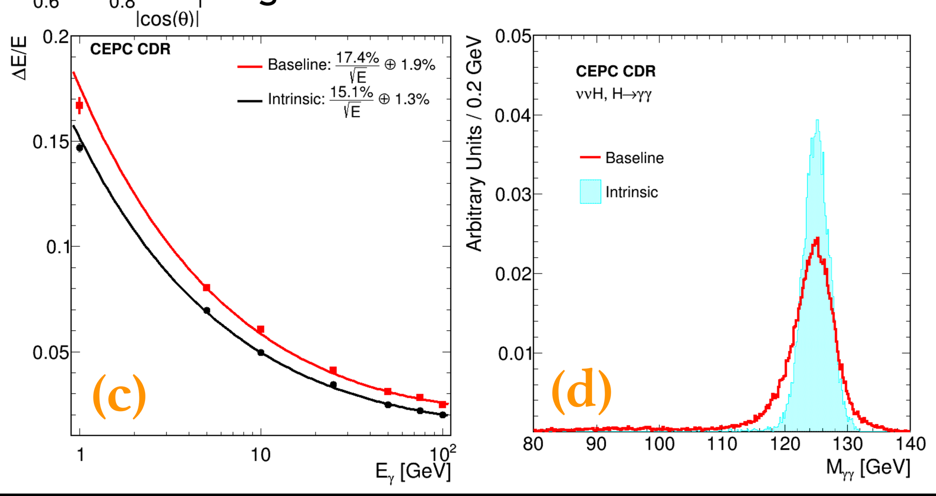


PHOTONS



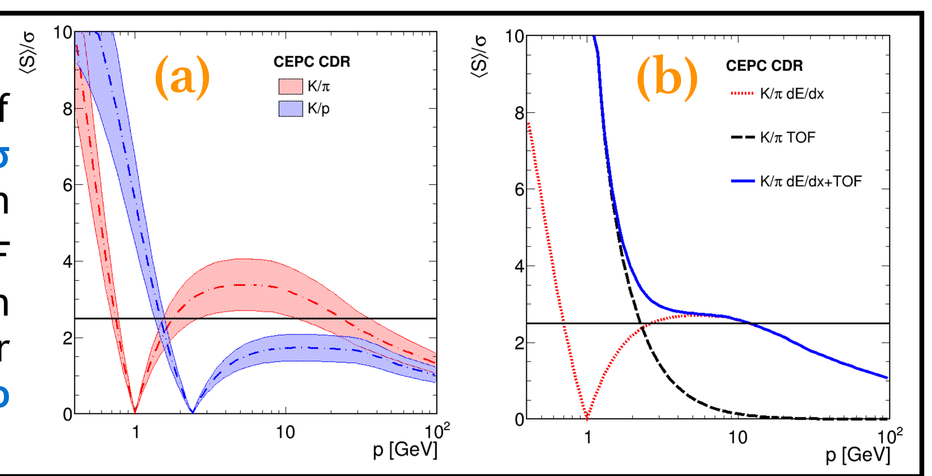
5-10% of photons in the central region and ~25% of photons in the forward region convert to e^+e^- parts through their interaction with the materials in front of the calorimeter. (a) shows the amount of material in the unit of radiation length. (b) show the photon conversion rates at different polar angles.

(c) compared the energy resolution of unconverted photons of the baseline detector concept with the intrinsic resolution of the calorimeter. The intrinsic resolution is obtained from MC simulation without material in front and gaps between modules. The photon energy resolution can be benchmarked using the diphoton mass distribution of the $H\to\gamma\gamma$ decay as shown in (d).



KAON IDENTIFICATION

Assuming a relative dE/dx resolution of 5%, the measurement could lead to 2-4σ separation of K/π for momentum between 2-20 GeV. Using both the ToF and dE/dx information, a separation better than 2σ could be achieved for charged particles with momenta up to 20 GeV.



SUMMARY

- Lepton: Efficiency of > 99.5% with a mis-id rate of < 1% for e and μ with momenta > 2 GeV, a relative mass resolution of 0.19% for the $H\to\mu^+\mu^-$ decay.
- Photon: Efficiency of nearly 100% with negligible mis-id rate from hadronic jets for uncovered photon > 5 GeV. Relative mass resolution of 2.5% for the $H\to\gamma\gamma$ decay.
- τ-lepton: Efficiency of 80% or higher and a purity close to 90% measured from $e^+e^-\to ZH\to q\bar{q}\tau^+\tau^-$ event at $\sqrt{s}$=240 GeV.
- Jet energy scale and resolution: JES can be measured with a sub-precent accuracy and a jet energy resolution of 3-5% is achievable for the CEPC, enabling a 2σ or better separation of the $W\to qq$ and $Z\to qq$ decays.
- Jet flavor tagging: efficiency/purity of 80%/90% for the b-jets tagging and 60%/60% for the c-jets tagging can be achieved for $Z\to qq$ sample of the Z factory operation.
- $K^\pm$ identification: K can be separated from π at 2σ for momentum up to 20 GeV, corresponding to efficiency/purity of 95%/95% for identifying K in the $Z\to qq$ sample integrated over the momentum range fo 2-20 GeV.

JETS FLAVOR TAGGING

Identification, i.e. tagging, of jet flavors is essential for the measurements of the Higgs boson couplings and the electroweak observables at the CEPC. Heavy-flavor quarks (b and c) from W, Z or Higgs boson decays hadronic quickly to form heavy bottom and charm hadrons (B^0, $B^\pm$, B_s, D^0, $D^\pm$, ...).

The jet flaovr tagging is performed using LCFIPlus, the tagging algorithm used for linear collider studies. LCFIPlus reconstructs secondary vertices from the final-state particles identified by ARBOR. (a-d) are the demonstration of the b/c-likeliness distributions of the b, c and gluon jets from the H→bb/cc/gg decays, showing good separations between jets of different flavors. (e) shows the b-jet tagging efficiencies for different rejections of background jets, measured from the Z→qq sample of the Z factory operation. About 20% of the Z bosons and 30% of the W bosons decay directly into final states with neutrinos. Searching for Higgs boson decays to dark matter particles is a key physics goal of the Higgs factory. The excellent energy and momentum resolutions of the CEPC baseline conceptual detector for visible particles allow for the determinations of missing energy and momentum with good precision. (f-g) shows the missing mass distributions fo events from, respectively, (Z→ qq, H→inv) and (Z→$\nu\nu$, H→bb/cc/gg) decays.