Design and performance of a new calorimeter : Stereo Crystal Electromagnetic Calorimeter

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Introduction

The physics research and feasibility of the next-generation Electron-Positron collider are currently under investigation, with the goal of precise measurement of the Higgs boson, the W and Z bosons as well as the top quark. The electromagnetic calorimeter (ECAL) in the barrel and endcaps enhances the detector system's capabilities for jet measurements----improves jet energy resolution and augments the capabilities to measure high momentum photons and electrons. We present a new design of crystal electromagnetic calorimeter, stereo crystal electromagnetic calorimeter (SCECAL), in which long trapezoidal crystals are the basic unit composing the SCECAL. By rotating a specific angle, a certain number of unit crystals can form a cylindrical detector. This novel design has several advantages: good energy resolution while keeping the mechanical structure relatively simple, uniform along Z, φ direction, and 2D readout in Z-φ plane with 3D positioning capability. A simulation model is established and the first results of the performance studies with the SCECAL design using CEPCSW (https://github.com/cepc/CEPCSW) are presented, including the energy resolution, position resolution, and the separation power of close-by particles.

Basic Concept of Stereo Crystal Electromagnetic Calorimeter

- The basic units of SCECAL are long trapezoidal crystals determined by a set of parameters: the inner radius of detector R1, the outer radius of detector R2, the angle with the inner radius of detector α, and the length of the side of trapezoid D (FIG.1 (a)).
- Long trapezoidal crystal (BGO as baseline) as basic unit.
- Detector layer: consists of a certain number of crystals rotated by specific angle: α (pointing angle)
- Adjacent layers are reversed to obtain better R segmentation(FIG.1 (b)).
- The maximum number of layers that a neutral particle starts from IP passes through the detector depends on α (FIG. 2).

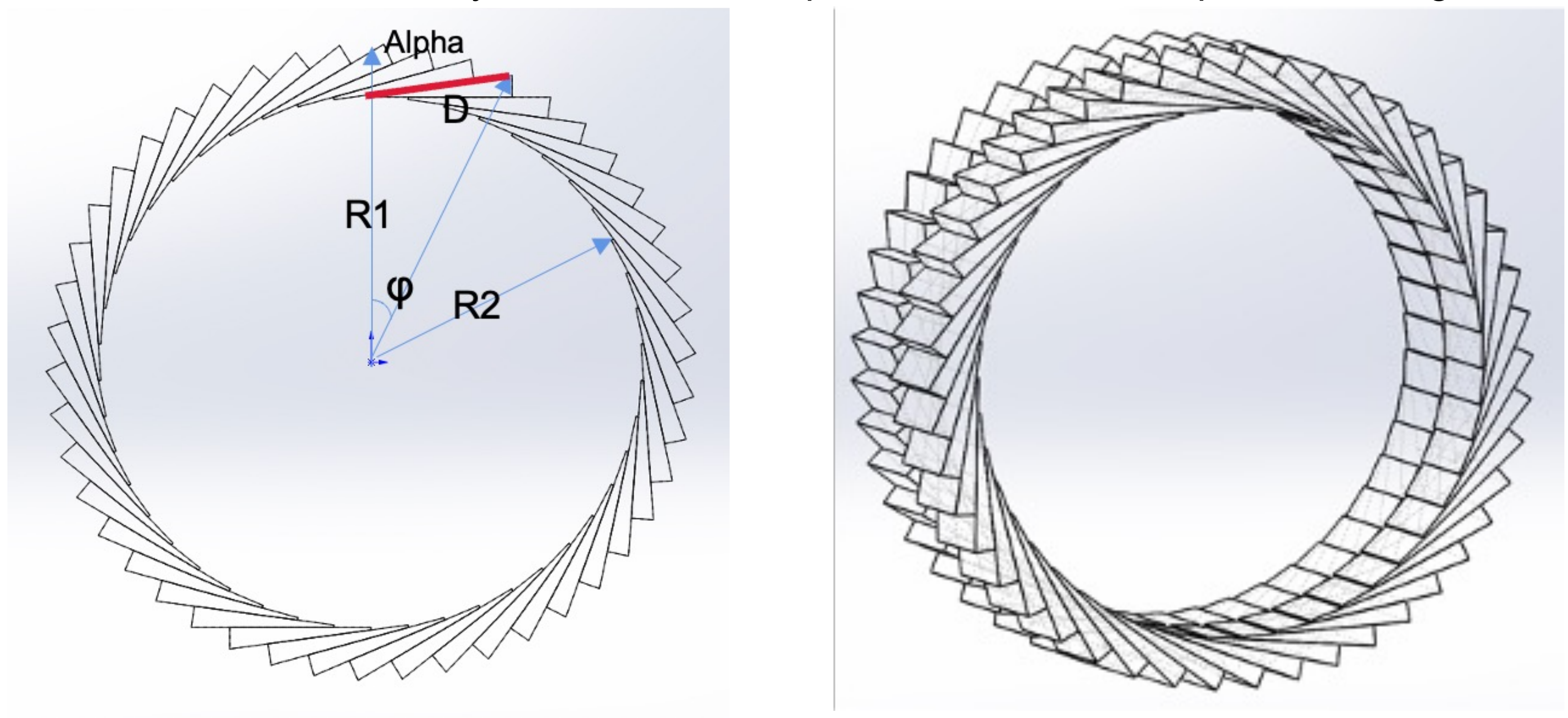


Figure 1. Schematic view of SCECAL.

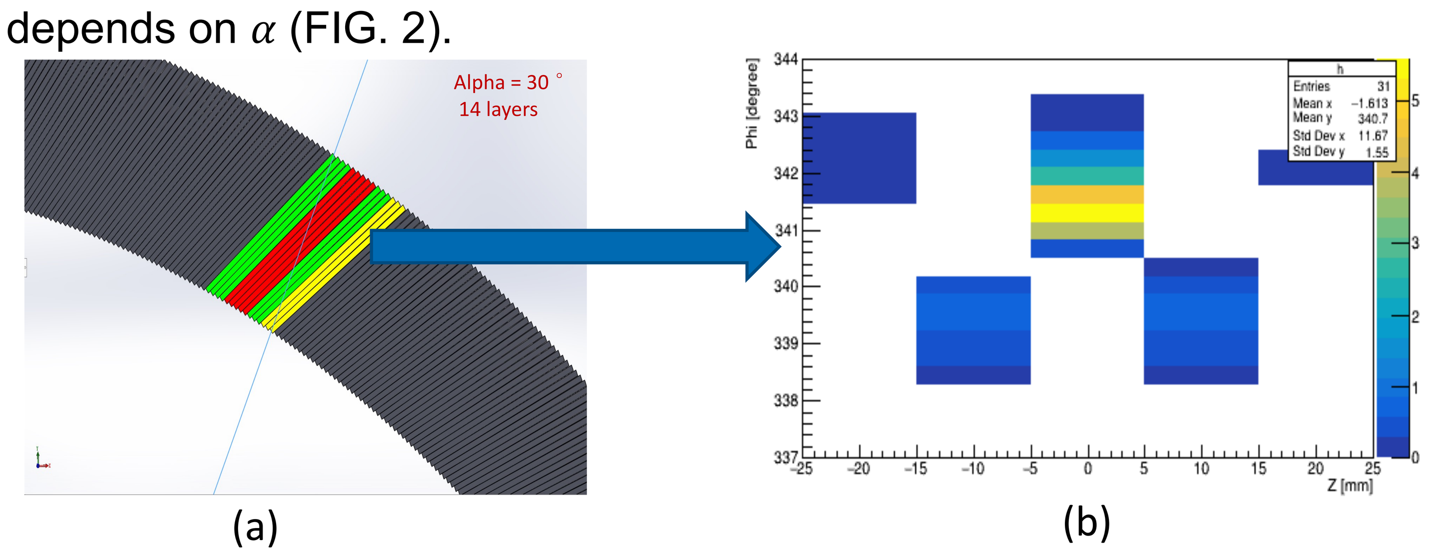


Figure 2.Event display in Z-Phi plane.

This novel design has several advantages:

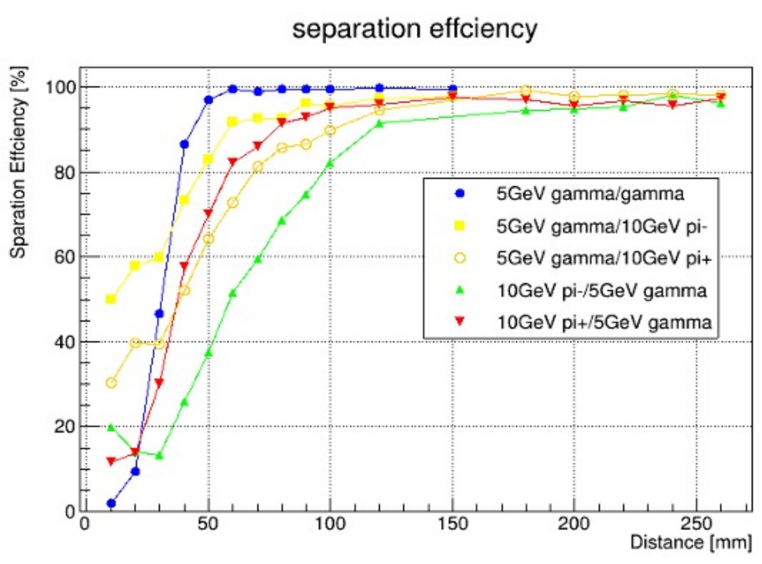
- Uniform along Z, ϕ direction
- Fine segmentation of Z, Phi, R
- 2D readout in Z-Phi plane, 3D positioning

Separation power of close-by particles

Simulation use CEPCSW , Reconstruction with (Naive method):

Energy clustering based on neighboring defined within the same Z index (see (FIG.1 (a)) :

- Split into 2 clusters if 2 local maximum energy found + extra Sel.
- Merge clusters in different Z index based on the geometric overlapping



γ/γ separation

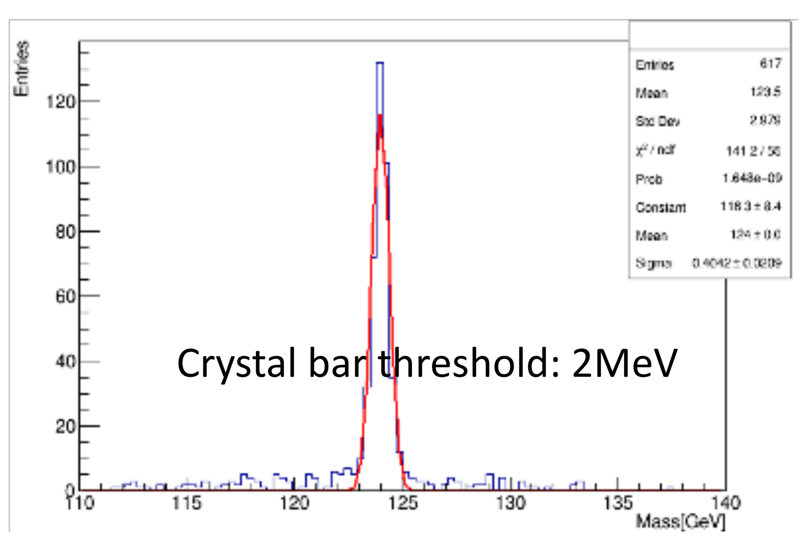
- Using two 5GeV γ, vary different distances in between
- Success reconstruction:
  - Find two neutral particles
  - 3.3GeV<E_γ <6.6GeV for each reconstructed particle

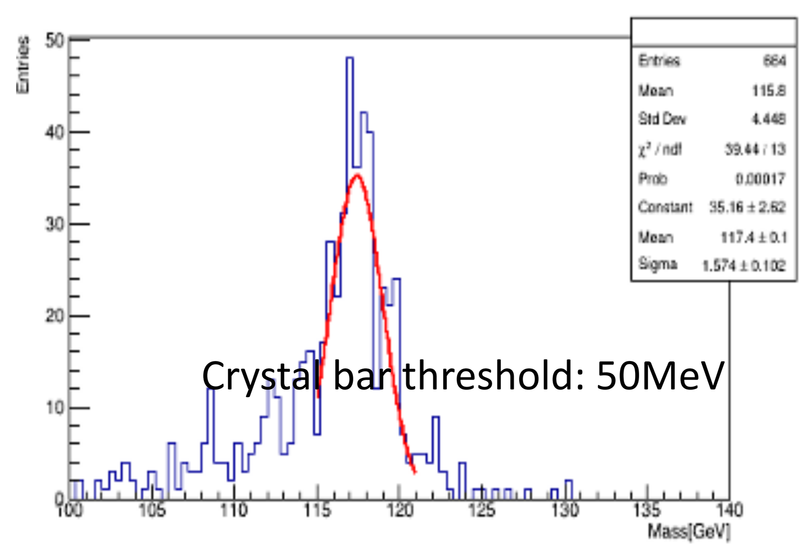
γ/π separation

- Using 5GeV γ & 10GeV π^+/π^-, vary different distance in between
- γ hits on the left/right side of π^+/π^-
- Success reconstruction:
  - Find one neutral particle
  - 3.3GeV<E_γ <6.6GeV
- Different π/γ separation power: due to the effect of geometry & magnetic field…

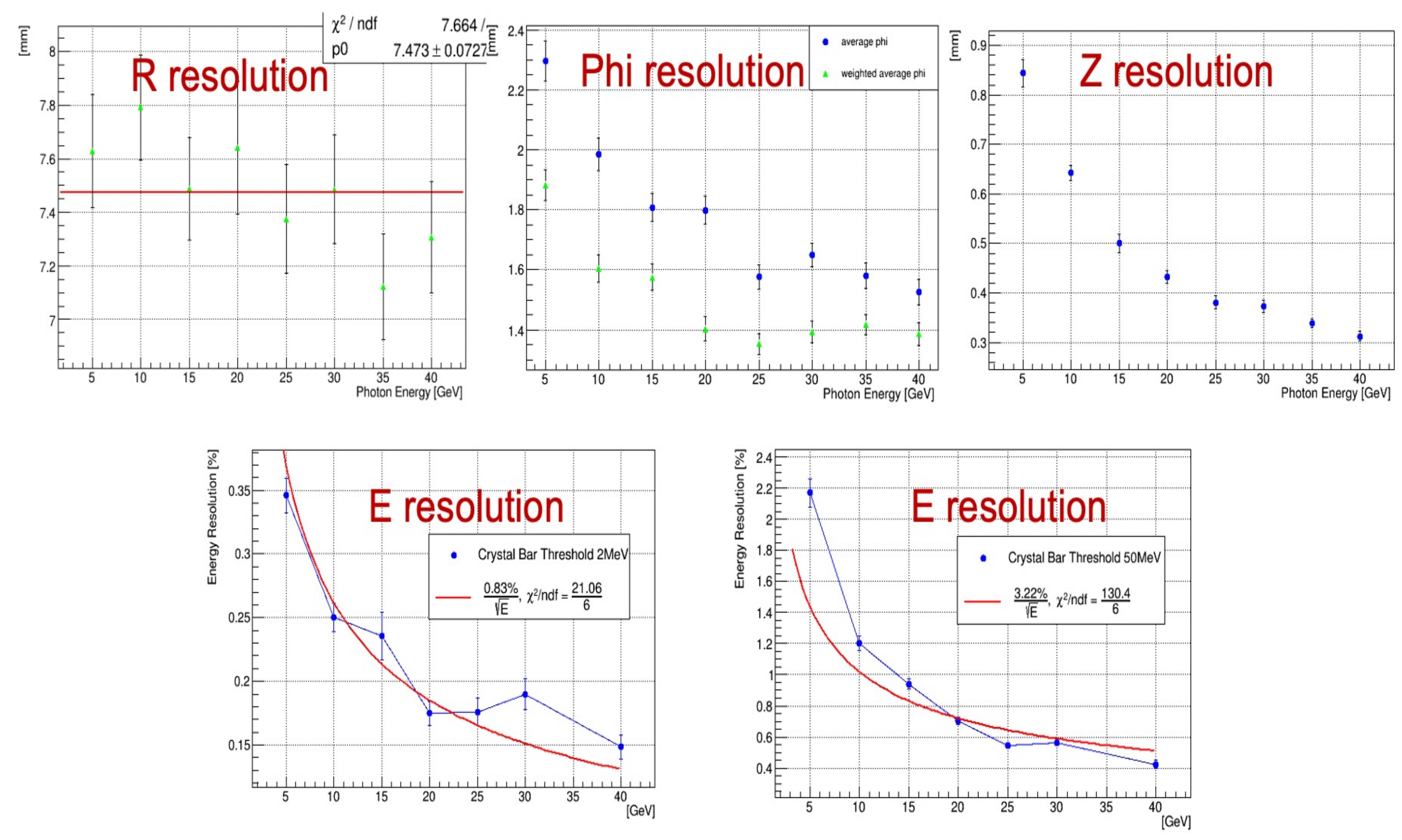
Boson mass resolution

- Using ZH-> γ/γ + 2 neutrinos at 240 GeV
- Success reconstruction:
  - Two particles are reconstructed





Energy and position resolution



- Simulations are done with events generated using SCECAL with alpha = 20 °
- The energy and position resolution is simulated by 5GeV photons:
  - Z resolution ~ 0.84 mm
  - Phi resolution ~ 1.9 mm
  - R resolution ~ 7.6 mm
  - Related to crystal bar energy threshold

Summary

In this work, we present simulation studies of SCECAL:

- 2D readout in Z-Phi plane, 3D positioning
- Uniform along Z, ϕ direction
- Good energy and shower 3D position resolution
- Good γ/γ & γ/π separation power
- Caveat: The performance of SCECAL depends on the reconstruction method and energy threshold, more efforts/fine tuning are in progress

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