Preliminary Exploration of a Crystal Based, Fast Timing ECAL Design

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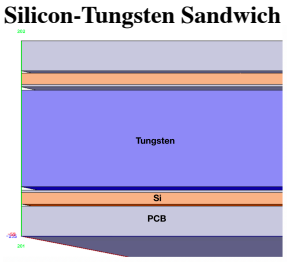
CDR Baseline ECAL

Sampling, PFA Oriented, 3D Readout

Two schemes:

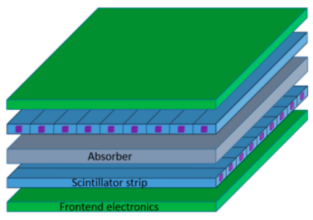
Silicon-Tungsten Sandwich ECAL



Basic Unit
- 2 symmetric sensitive **silicon layers**
  - glued on a PCB
  - equipped with readout ASICs
- 1 **tungsten plate**

Scintillator-Tungsten Sandwich ECAL

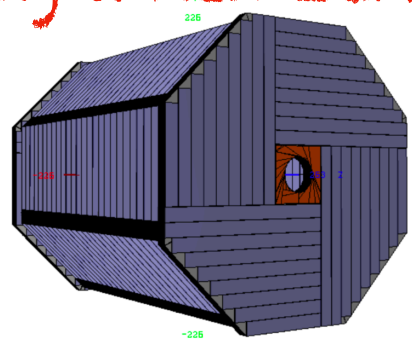
Basic Unit
- 2 layers of **plastic scintillator strip**
  - 2mm thick, 5×45mm² large
  - perpendicular to adjacent layer
  - attached to SiPM
- 1 **tungsten plate**



Defects:

1. Limited **Energy Resolution**, especially for Low Energy Photon.
2. **Cost**, **Power consumption** and **Cooling**.

Why a new ECAL?



ECAL Geometry in CEPC CDR

New ideas about ECAL

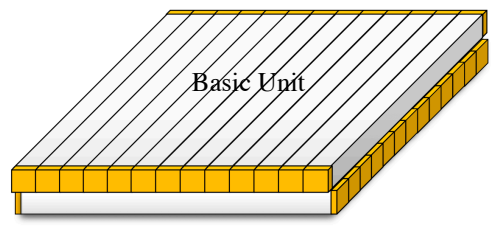
Full Crystal, Fast Timing, 2D Readout

Basic Module

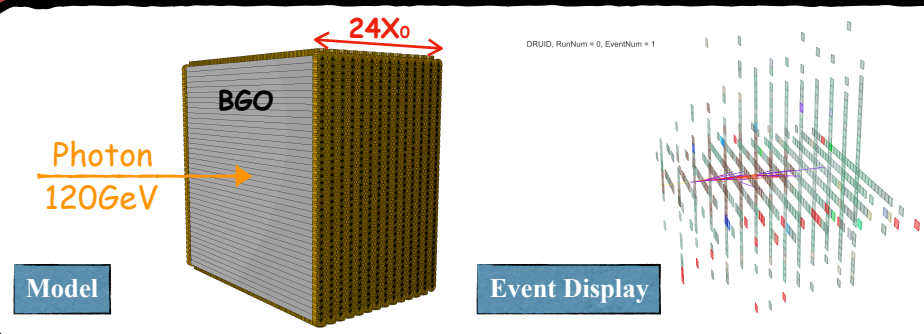
Crystal Scintillator (eg. BGO, LYSO…)

$1\times1\times40cm^3$

Photodetectors (eg. FPMT, SiPM…)



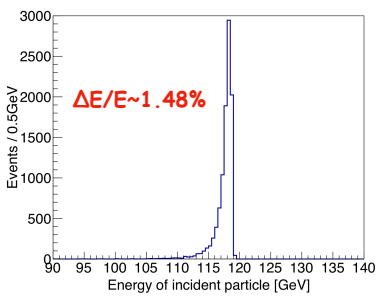
In order to reduce the number of electronic readout channel, **precise time measurement** is expected.

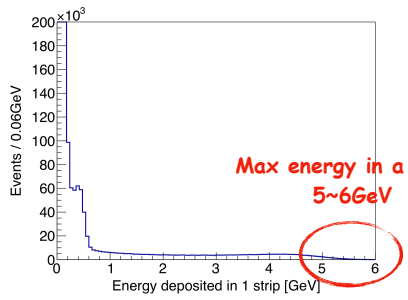


Analysis at Energy Deposition Level

Energy Resolution

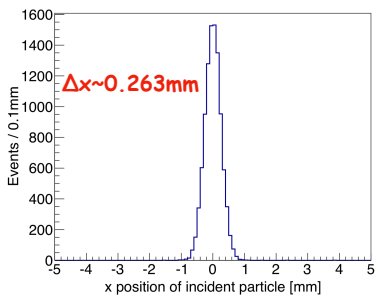
For a basic ECAL unit with $24X_0$, energy resolution at energy deposition level is about 1.48% @120GeV.
The maximum energy deposited in a BGO strip ($1\times1\times40cm^3$) for a 120GeV photon is about 5~6GeV. This result can be an input for the saturation and design of electronics.

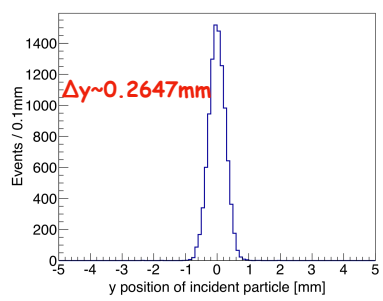




Position Resolution

Position of incident particle is reconstructed by center of energy deposition in each layer. Position resolution can reach about 265μm @120GeV.

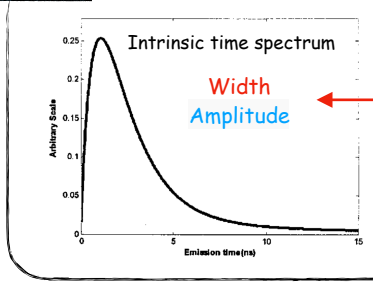




Intrinsic Time Resolution of Crystal

Except for the electronics and photodetectors, some properties of crystal itself (see the list below) can contribute to the time resolution. We call it **Intrinsic Time Resolution**.

Factors



- Hitting Position of incident particle
- Incident angle of incident particle
- Geometry size of crystal (cross section)
- Reflectivity of reflectance coating
- Scintillation properties of crystal
  - Scintillation yield
  - Decay time
  - Absorption length
- .....

So far, we have studied the dependence of the intrinsic time resolution of crystal on the hitting position of incident particle. The setup and results of scan are shown below.
For a $1\times1\times40cm^3$ BGO strip, intrinsic time resolution of single readout is in the range of 15~120ps (Fig.1). And the time measured by two PMTs is independent (Fig.2). So we can get a combined time resolution below **50ps** corresponding to **1cm** position resolution along crystal strip.

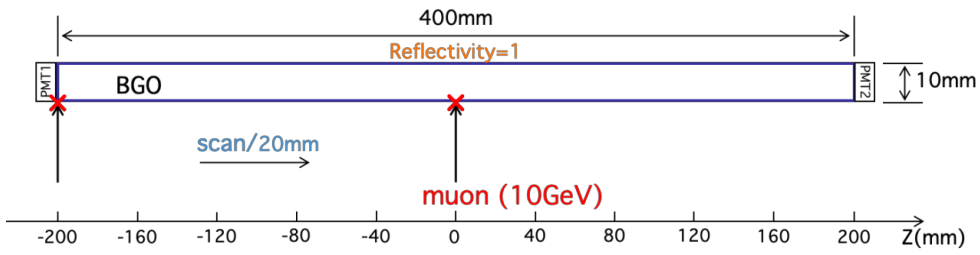


Fig.1

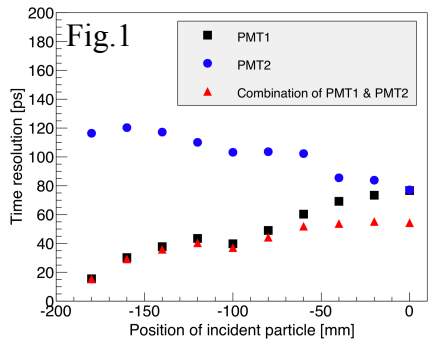
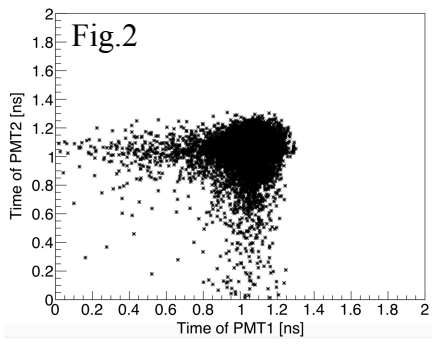


Fig.2



Conclusion and Next Step

- ✦ New ECAL geometry with crystal strip can achieve high energy resolution (~1.48% @120GeV) and high position resolution (~265μm @120GeV) for a single photon at the level of energy deposition in Monte Carlo Truth. Further simulation with dedicated digitization modeling the electronic responds and inhomogeneity noise is needed in the next step. Analysis including more energy points is also necessary.
- ✦ More detailed analysis about dependence of the intrinsic time resolution on other parameters of crystal will be conducted.
- ✦ Capability of separating two nearby Particle-Showers is vital to a ECAL. We need to do:
  - Analysis of physics requirement of separation (How severe is the overlap for the new geometry in a CEPC event with most abundant final state particles?)
  - Exploration of separation algorithm (How to do the separation?)