# Detector geometry and PFA reconstruction for the crystal bar ECAL in CEPC

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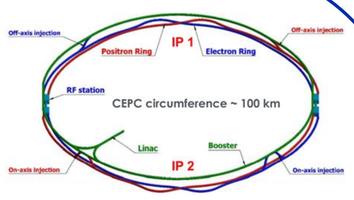
## Introduction

**Circular electron positron collider (CEPC):**

Precise measurement of Higgs, EW, top, flavor, QCD… BSM physics.




**Detector requirement:**

For hadronic final states $W^{\pm}/Z/H \to q\bar{q}$: BMR<4%.

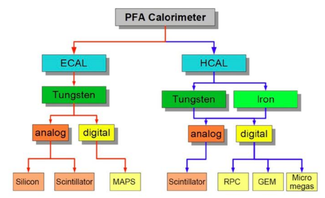
**Particle Flow Approach:**

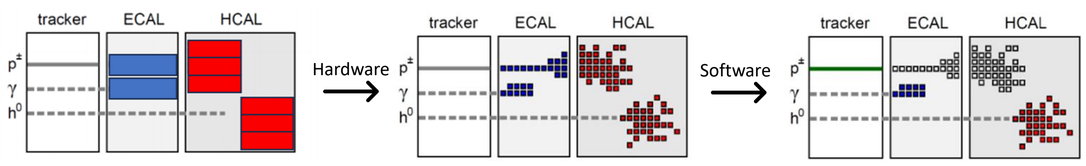
$E_{jet} = E_{tracker} + E_{ECAL} + E_{HCAL}$

Hardware: high granularity and compact shower.

Software: clustering and pattern recognition.

CALICE: high granularity sampling calorimeter and PandoraPFA.




**Homogeneous crystal calorimeter:**

Long history in particle physics precise measurement.

Bright light: $\sigma_E/E \sim 3\%/\sqrt{E}$.

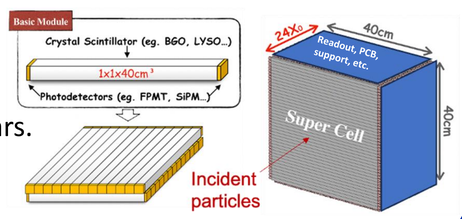
Fast response: time information.

**Novel crystal ECAL**: orthogonal arranged crystal bars.

Double-end readout with SiPM ($Q$, $T$).

Cross-location by bars.

Less readout channels, lower cost.



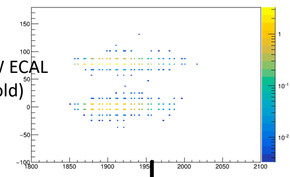

## Particle flow reconstruction

$\boldsymbol{\sigma_{jet}} \sim \sigma_{trk} \oplus \sigma_{EM} \oplus \sigma_{Had} \oplus \boldsymbol{\sigma_{confusion}}$: Confusion is an important limitation factor

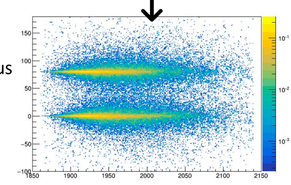
1.Larger $R_M$ & smaller $\lambda_I/X_0$ and more shower overlap: need **energy splitting**.

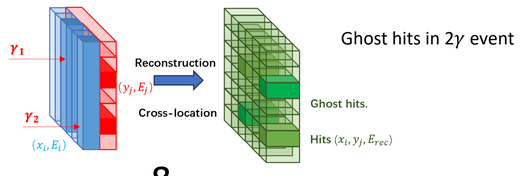
2.Multi-particle ambiguity: need **ambiguity removal**.

Sampling SiW ECAL (with threshold)



Homogeneous BGO ECAL



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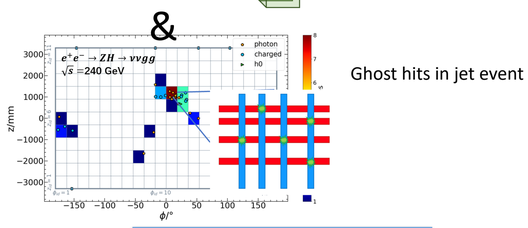



A particle flow reconstruction algorithm aiming at addressing key issues in long crystal bar ECAL design is progressing smoothly and show promising results.

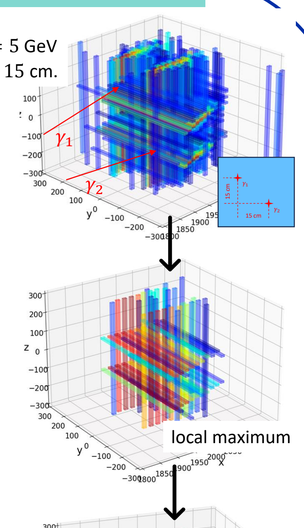
Software task:
* Clustering
* Pattern recognition.
+ Overlap: energy splitting.
+ Ambiguity problem.

## Reconstruction algorithm

Based on preliminary detector geometry

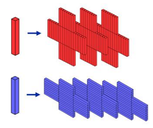
Ideal digitization and no supporting, mechanics, etc.

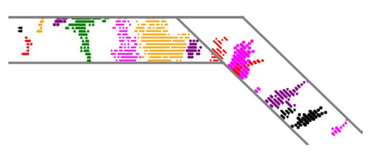
2 photons, $E_\gamma = 5$ GeV
Distance = $15 \times 15$ cm.




**1. Clustering:**

Global neighbor clustering in 2 directions.



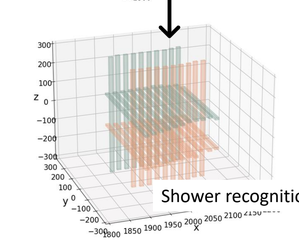


**2. Shower recognition:**

a. Use the local maximum to simplify the pattern

b. Three individual algorithms for different type:

c. A set of topological cluster merging.

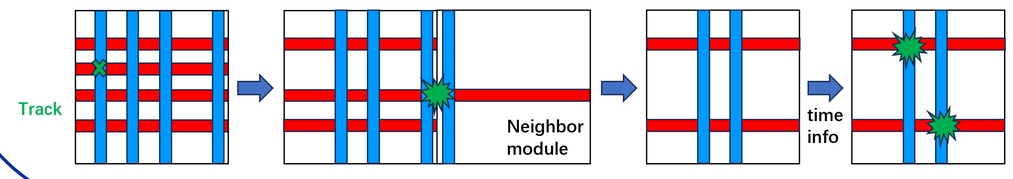



**3. Splitting for the overlapped shower:**

Calculate the expected energy deposition from EM profile.

**4. Ambiguity removal:**

Information from track, neighbor tower and time.

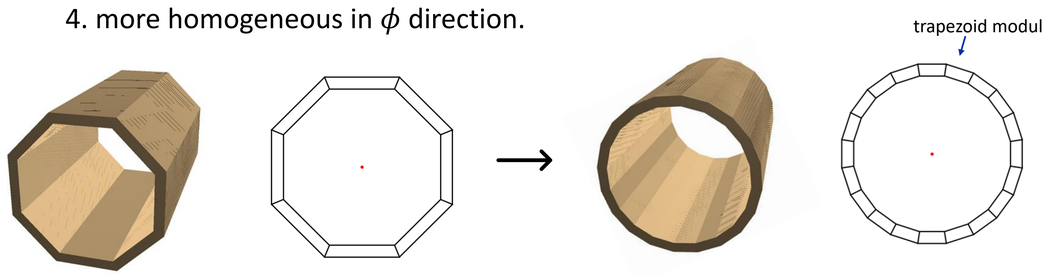



## Crystal ECAL geometry

**Nearly cylindrical barrel ECAL:** polygon configuration of inner boundary

**With more polygon sides**

1. minimize the gap between tracker and ECAL.
2. decrease outer radius of ECAL and reduce cost of outer subsystems like solenoid.
3. decrease volume of crystal.
4. more homogeneous in $\phi$ direction.




Key issue in geometry construction:

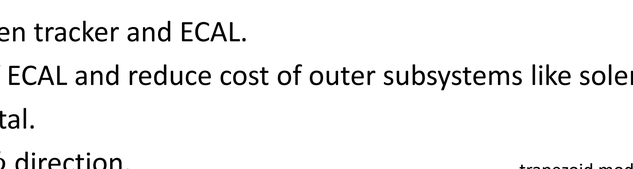
Not self-supporting and need supporting mechanics: need **deal with energy leakage**.

## Crystal placement

**Cracks between crystal modules**: supporting structure (carbon fiber) and electronics (SiPM, PCB and ASIC) .

**Projective cracks** cause a decrease of detection efficiency and energy leakage for neutral particles which will deteriorate physics results like mass distribution of $H \to \gamma\gamma$.



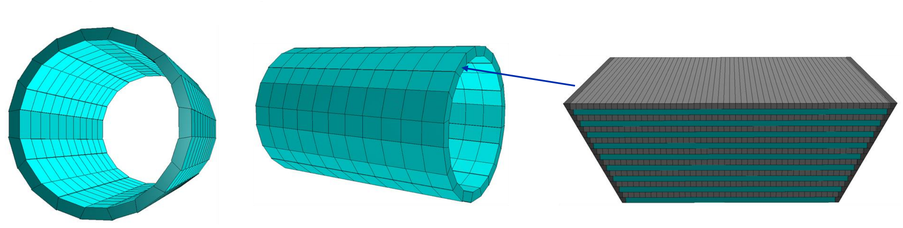




**Make cracks non-projective** by displacement of crystals: drop of detection efficiency is smeared out.




**Trapezoids and upside-down trapezoids arranged in sequence:** make ECAL more homogeneous.

Detector description including geometry and material (BGO) is complemented using DD4hep in CEPCSW: parameterized and automated.

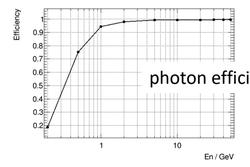


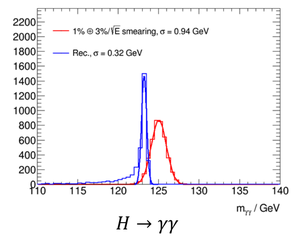
## Algorithm performance

**Photon recognition efficiency ~100%** for $\gamma$ with $E > 1GeV$.

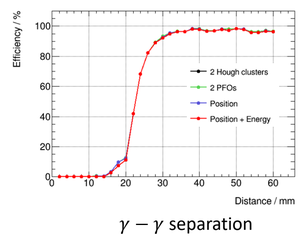
$H \to \gamma\gamma$ reconstruction: $\boldsymbol{\sigma(m_{\gamma\gamma})} \sim \mathbf{0.32\ GeV}$.

$\boldsymbol{\gamma - \gamma, \gamma - \pi}$ **separation efficiency ~95%** with distance > 30mm.

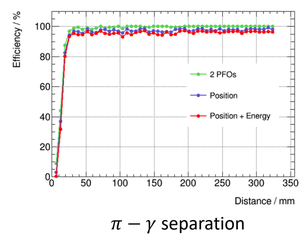



$H \to \gamma\gamma$




$\gamma - \gamma$ separation




$\pi - \gamma$ separation

## Conclusions

A novel design of crystal ECAL for the future lepton colliders:

New homogeneous ECAL design, better energy resolution, less readout channels.

Can be compatible with Particle Flow and match the physics requirement.

A nearly cylindrical barrel crystal ECAL geometry construction is proposed:

Make cracks non-projective by crystal displacement avoiding drop of detective efficiency.

Geometry with trapezoids and upside-down trapezoids arranged in sequence.

A new pattern recognition PFA for this new design:

Main challenges in the software are the overlapping and ambiguity.

Series of algorithms are developed and show promising results.

Final reconstruction of jets and Boson Mass Resolution (BMR) is under developing.

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on behalf of the CEPC ECAL software working group