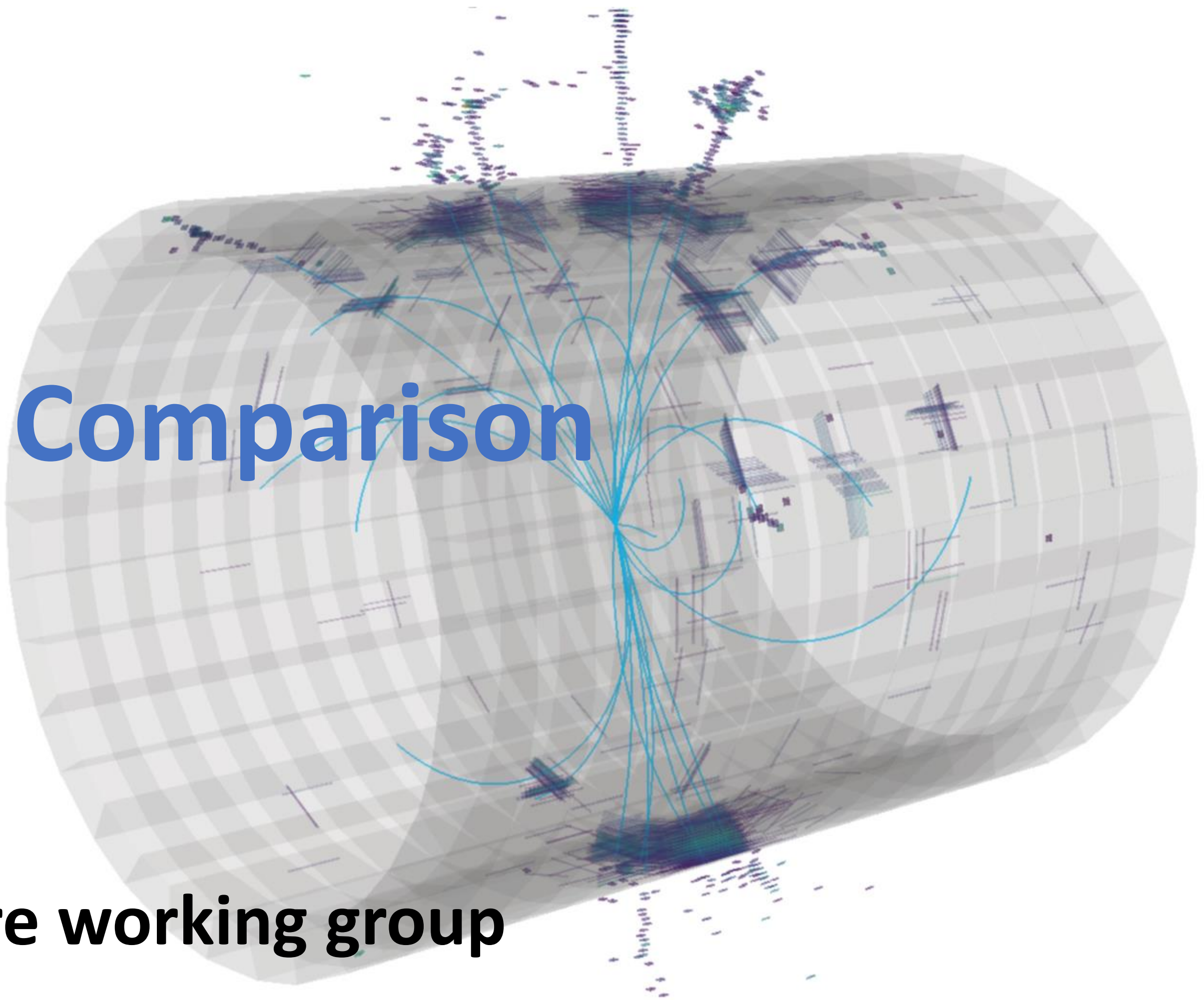
10mm vs. 15mm Crystal Comparison Using CyberFPA



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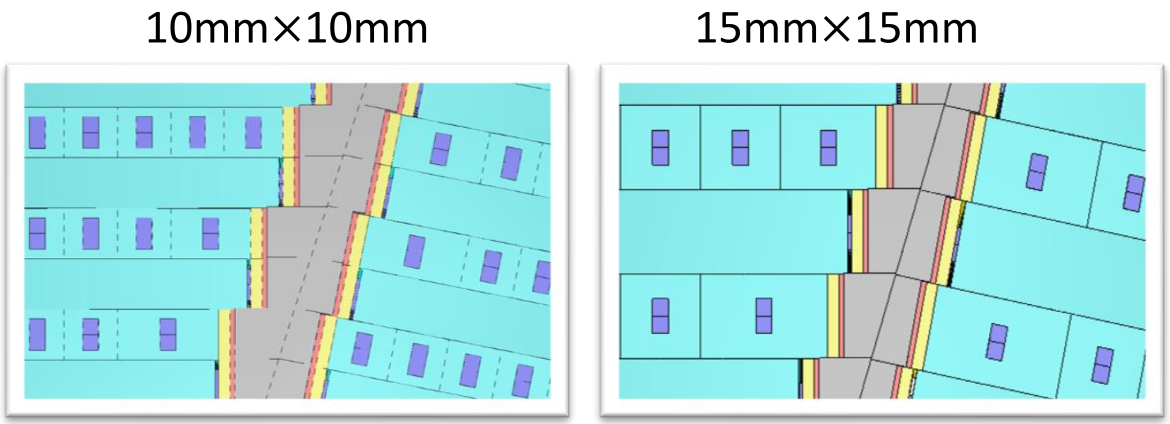
Introduction

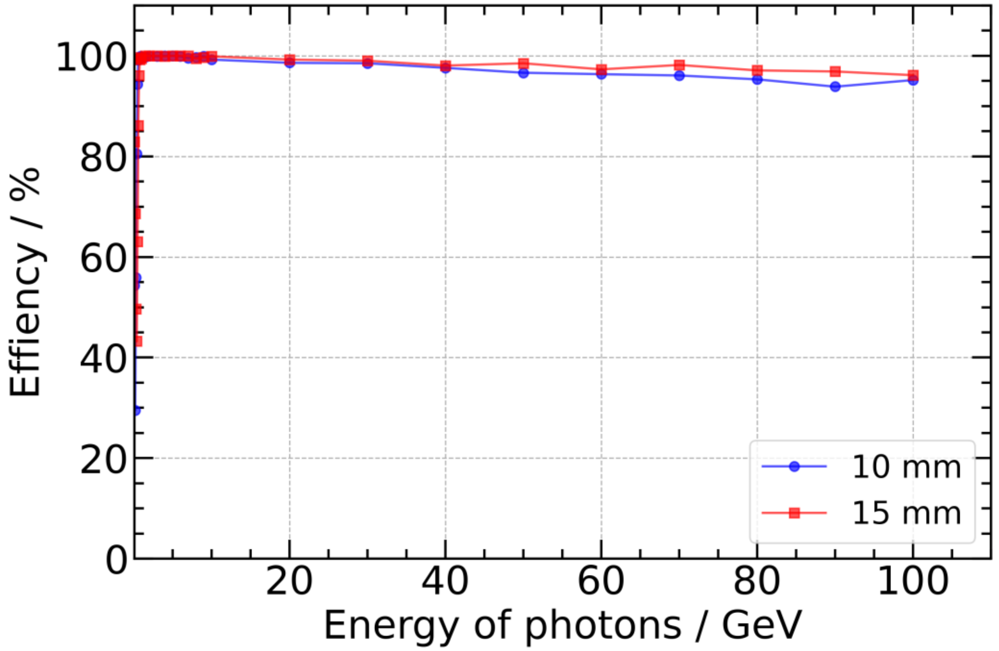
- **10mm and 15mm granularity geometry display**
- **10mm ➔ 15 mm:**
  - Advantages:
    - Similar crystal volume, significant reduction in number of readout channels (956160-405120)*11.5EUR = 6.3M EUR
    - Less dead area: one step per 2 layers for 10mm, one step per layer for 15mm 13.8% → 12.4%
    - Reduce difficulty of mass production of crystal bars
    - Mechanics(cooling) and electronics benefit from larger granularity
  - Disadvantages:
    - Lager granularity deteriorate particle recognition
- **Physics performance study**
  - One step per 2 layers for 15mm in this study: 1 week
  - Energy correction for cracks needs update

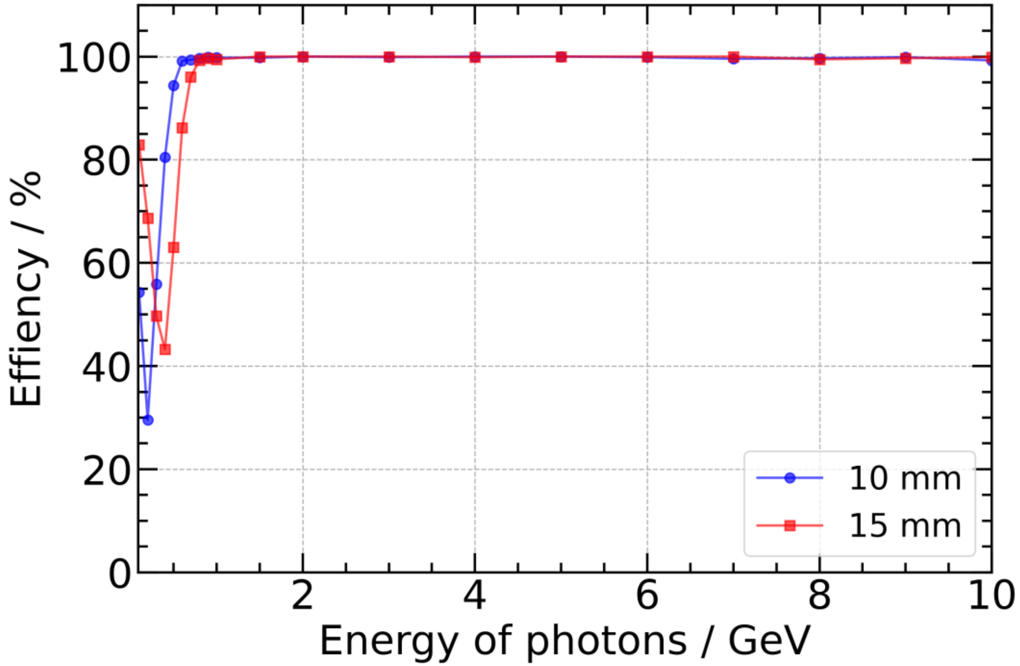


Granularity	Number of Readout Channels
10 mm	956,160
15 mm	405,120

Efficiency of γ Recognition

- γ
  - $E_{\gamma}: 0.1 \sim 100 GeV$
  - $\theta = 91°, \phi = 0°$
  - $N_{cluster} \geq 1$
  - $|E_{cluster} - E_{truth}| < 5\sigma$

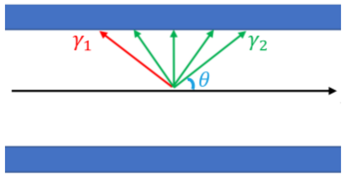


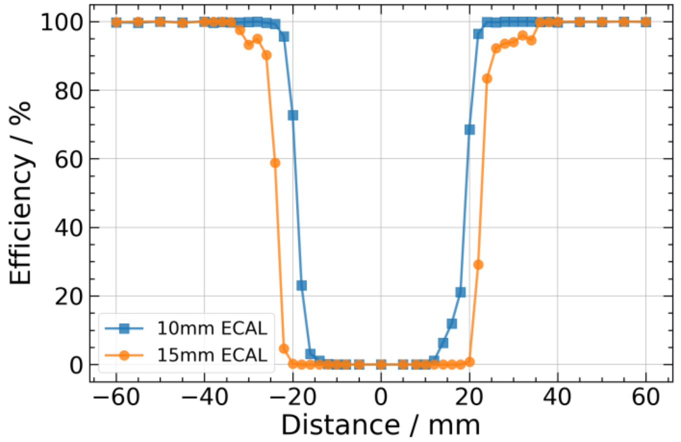


Veto particles with interactions in front of ECAL

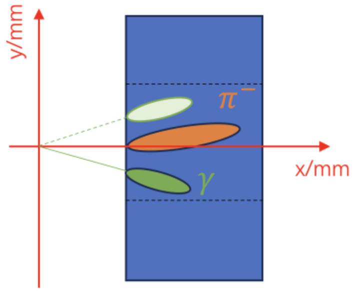
Separation Capability

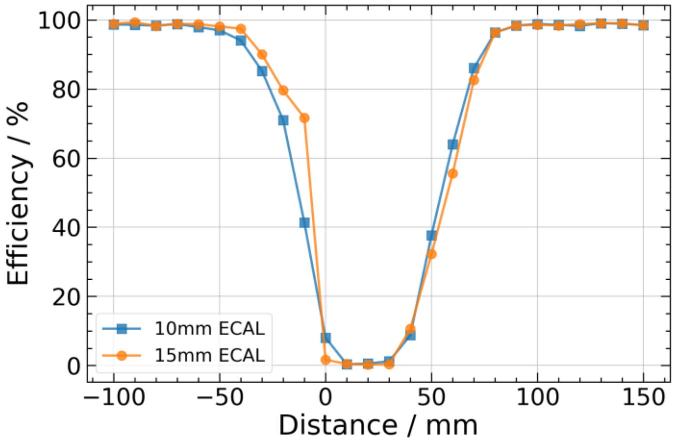
- $\gamma\gamma$
  - $E_{\gamma 1} = E_{\gamma 2} = 5GeV$
  - Success separation:
    - ≥2 PFO,
    - $|E_\gamma - E_{PFO}| < \frac{1}{3} E_\gamma$
    - $|\theta_\gamma - \theta_{PFO}| < 0.3$ for 10mm ECAL, <0.45 for 15mm ECAL





- $\gamma\pi$
  - $E_\gamma = E_{\pi^-} = 5GeV$
  - Success separation:
    - 1 charged PFO, ≥1 neutral PFO
    - $|E_\gamma - E_{neutral\ PFO}| < \frac{1}{3} E_\gamma$
    - $|y_{gamma} - y_{PFO}| < 30mm$



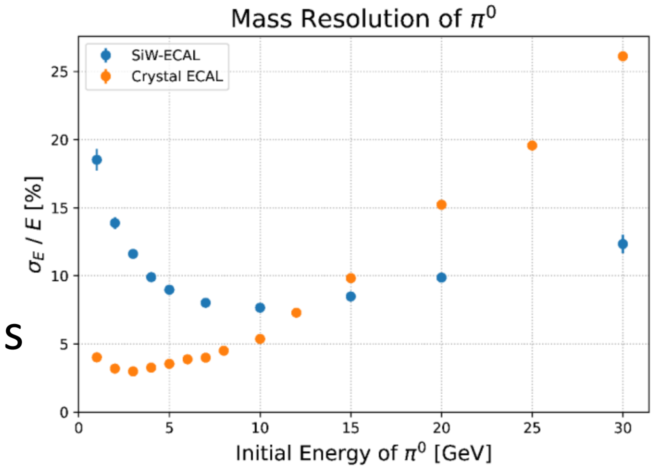


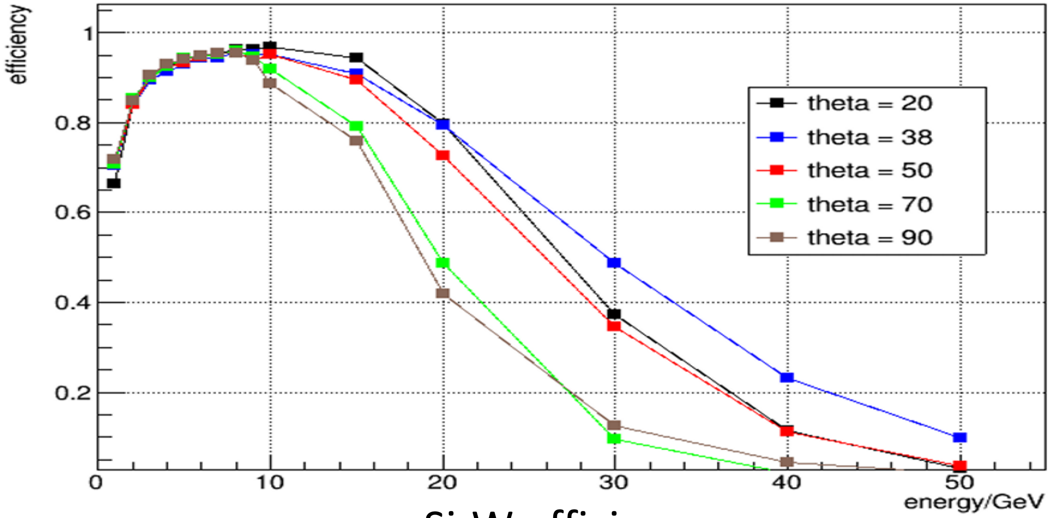
Veto particles with interactions in front of ECAL

Mass Resolution and Efficiency of π^0

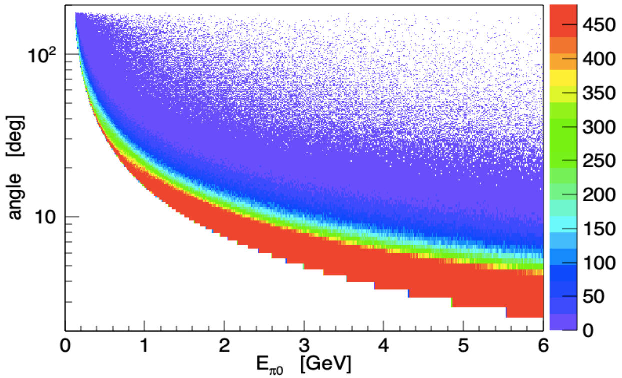
- π^0
  - $E_{\pi^0}: 1, 2, .., 28$ GeV
  - $\theta: 50° \sim 130°$
  - $\phi: 0° \sim 360°$

Veto particles with interactions in front of ECAL

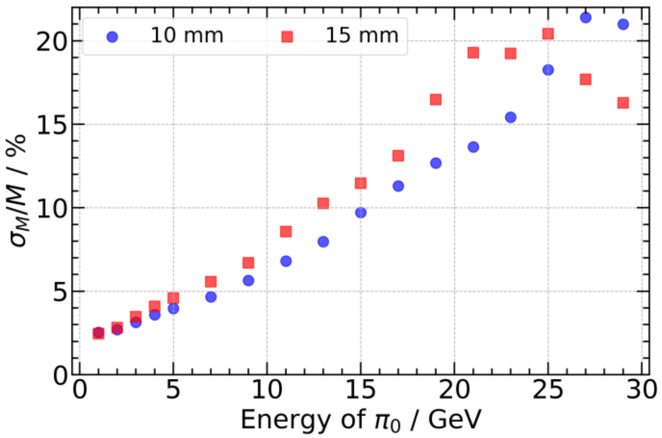




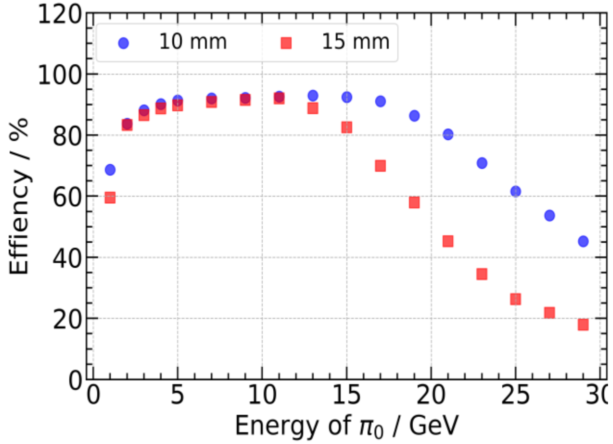
Si-W efficiency



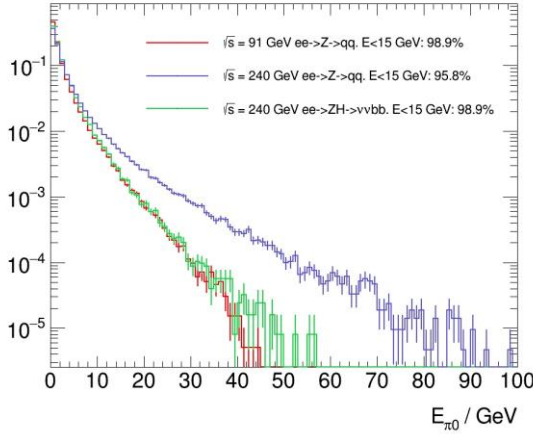
Angles of 2γ vs Energy of pi0



Crystal resolution

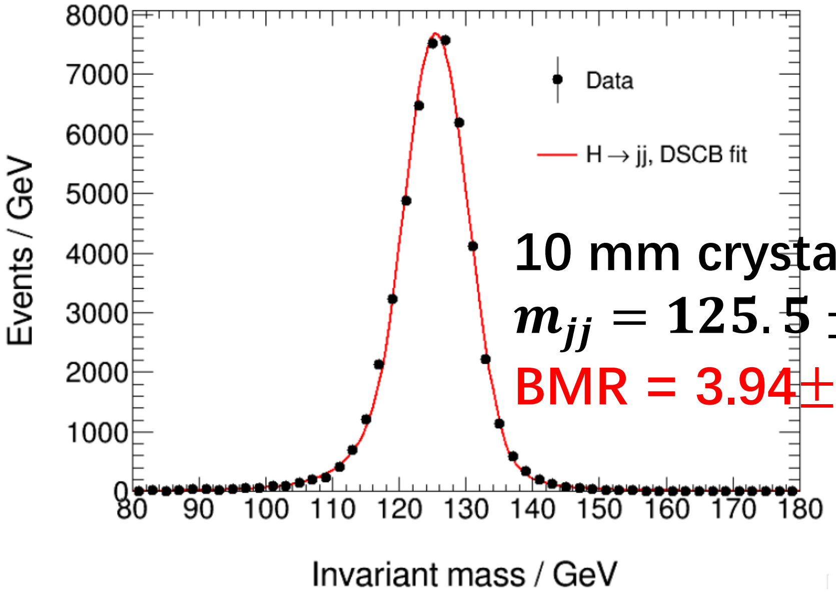


Crystal efficiency

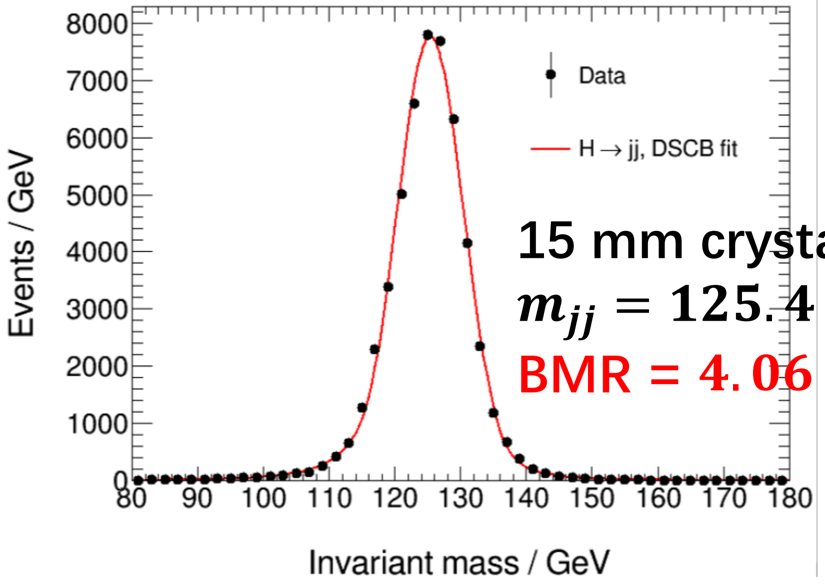


Preliminary BMR performance

- **Full detector reconstruction: track + ECAL (10 mm / 15 mm) + GS-HCAL**
  - Track selection: a BDTG-based selection.
  - ECAL and HCAL digitization are the same for 10 mm and 15 mm.
  - CyberPFA reconstruction: tuned granularity related parameters.
  - ~200k events generated, ~ 50k selected for barrel only.



10 mm crystal bar ECAL
$m_{jj} = 125.5 \pm 4.94$ GeV
BMR = 3.94$\pm 0.03\%$



15 mm crystal bar ECAL
$m_{jj} = 125.4 \pm 5.09$ GeV
BMR = $4.06 \pm 0.04\%$

BMR performance

- **Previous studies about ECAL granularity:**
  - PandoraPFA: *"For 45 GeV jets, the dependence is relatively weak since the confusion term is not the dominant contribution to the resolution. For higher energy jets, a significant degradation in performance is observed with increasing pixel size."*
  - ArborPFA: *"with the ECAL cell size is at 10 mm, the overlapping chance is 1.7% only. However, once the ECAL cell size increases to 20 mm, this overlapping chance rapidly increases by one order of magnitude."*

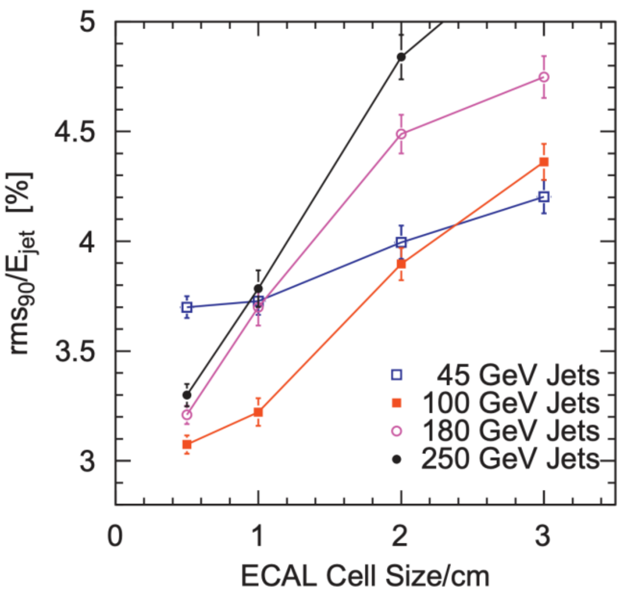


Table 2. Percentages of photons that would be polluted by neighbor particles

Cell Size	Critical Separation Distance with Arbor	Percentage of $Z \to \tau^+\tau^-$
1 mm	4 mm	0.07%
5 mm	8 mm	0.30%
10 mm	16 mm	1.70%
20 mm	38 mm	19.6%

Table 3. Resolution of reconstructed Higgs boson mass through $\nu\nu Higgs, Higgs \to gluons$ events with different cell size at CEPC_v1 geometry.

Silicon sensor cell size	Higgs boson mass resolution (Statistic error only)
5 mm	3.74 ± 0.02 %
10 mm	3.75 ± 0.02 %
20 mm	3.93 ± 0.02 %

Plan of CyberPFA

- **Short term goals (1 months)**
  - Granularity 15mm*15mm*400mm crystal ECAL Comments 4 / ECAL Issues 5 / Calo Recommendations 2
  - Endcap of ECAL → Preliminary result → Further tuning Software Recommendation 3
  - Performance studies ECAL Comments 1 / Calo Recommendations 3/ Software Recommendation 2
    - Single particles (γ, π^0, $\pi^{\pm}$, K_L/n) for detector performance Performance Recommendation 2
    - Complex physical processes ($H/Z \rightarrow udscb\ g$, w/ ISR etc.)
  - PID information
- **Medium term goals (5 months)**
  - Sequential improvements of tracking ECAL Comments 1
  - Beam-induced backgrounds analysis
  - Calibration and correction of energy deposition Performance Recommendation 7
  - Optimization of HCAL algorithm ECAL Comments 1
- **Long term goals (2 years)**
  - Optimization of ambiguity removal algorithm
  - ECAL energy splitting

ECAL Comments 1