Simulation studies of PFA hadronic calorimeter with scintillating glass

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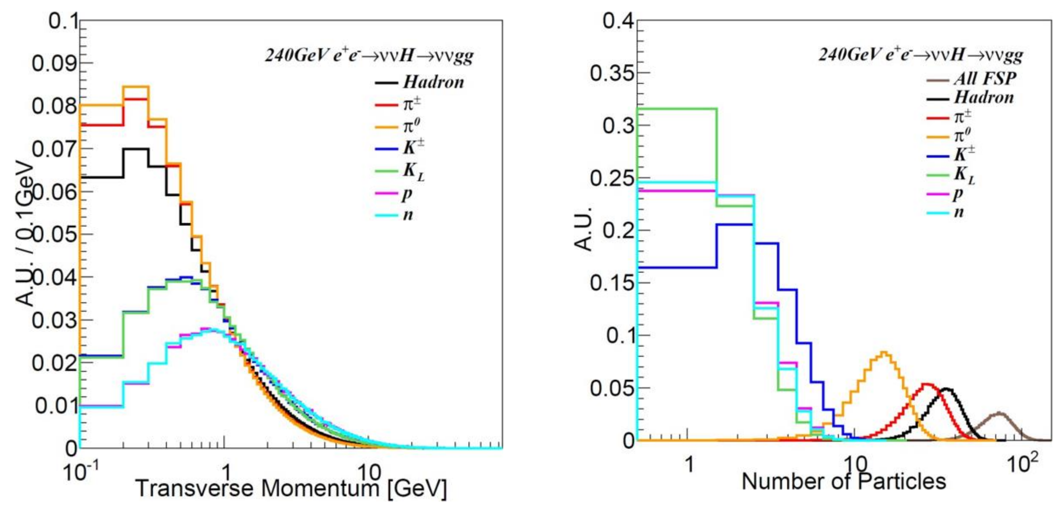
On behalf of the CALICE Collaboration and the Glass Scintillator Collaboration

Introduction

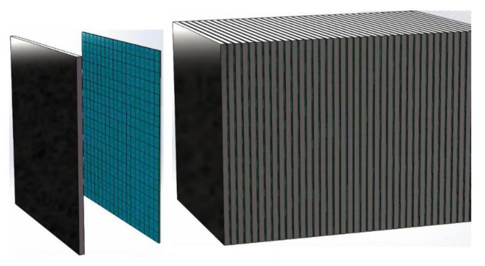
High energy electron-positron collider experiments have been proposed for precision measurements of the Higgs boson and explore new physics beyond the Standard Model. The Circular Electron Positron Collider (CEPC), as one option among next generation colliders as Higgs factories, requires accurate identification and reconstruction of all final states from Higgs, W and Z bosons. Therefore, the jet energy resolution of the CEPC detector need to achieve $\sim 30\%/\sqrt{E_{jet}(GeV)}$, which poses challenges for the calorimetry system. A feasible paradigm to achieve this goal is the high granular calorimetry based on the particle flow algorithm (PFA).



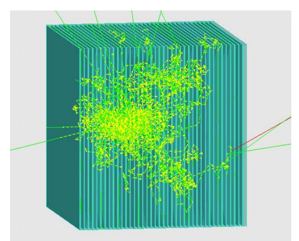
As the majority of jet components at Higgs factories with the center-of-mass energy of 240 GeV are with relatively low energy (mostly below 10 GeV), a better hadronic energy resolution would be useful for better PFA performance and jet measurement precision. Hereby, we propose a new design for a highly granular HCAL with high-density scintillating glass tiles, with a higher-energy sampling fraction and PFA compatibility, to further improve the hadronic energy resolution. Its detector layout generally is similar to the CALICE scintillator-steel hadronic calorimetry (AHCAL) technique, proposed in the CEPC Conceptual Design Report, but instead of plastic scintillator, scintillating glass tiles are instrumented.

1. HCAL design and potentials

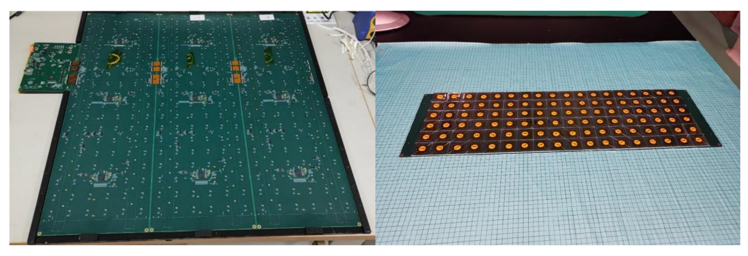
- CEPC CDR baseline: Scintillator-Steel AHCAL
  - 40 sampling layers
    - Plastic scintillator (sensitive): 3 mm thick
    - Steel (absorber): 20 mm thick
  - Tile size: $30\times30\ mm^2$
- Scintillating glass HCAL
  - Replace plastic scintillator with scintillating glass
  - Glass tile design: ongoing optimization



CEPC AHCAL prototype schematics

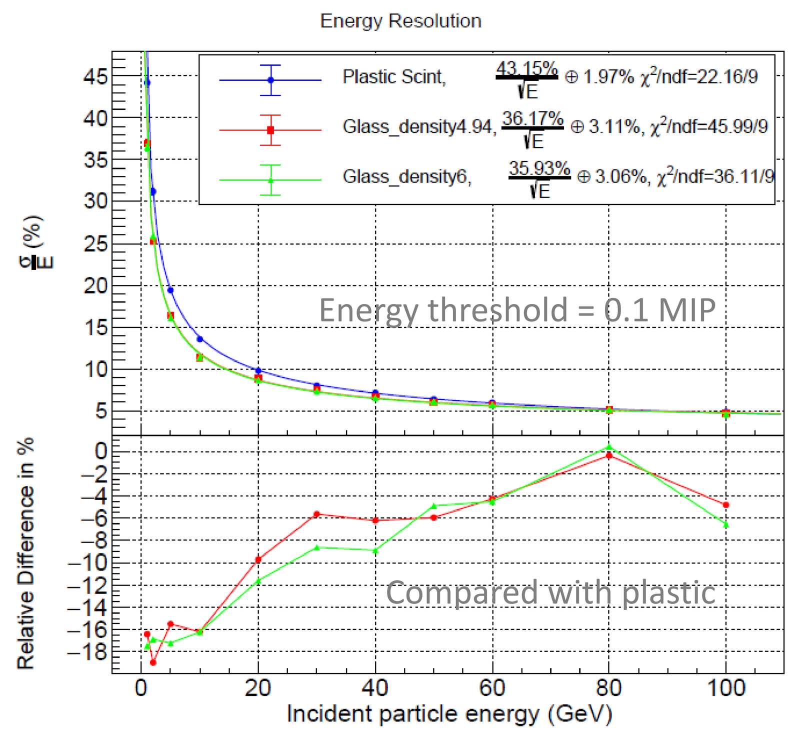


Event display



Single layer of CEPC AHCAL prototype

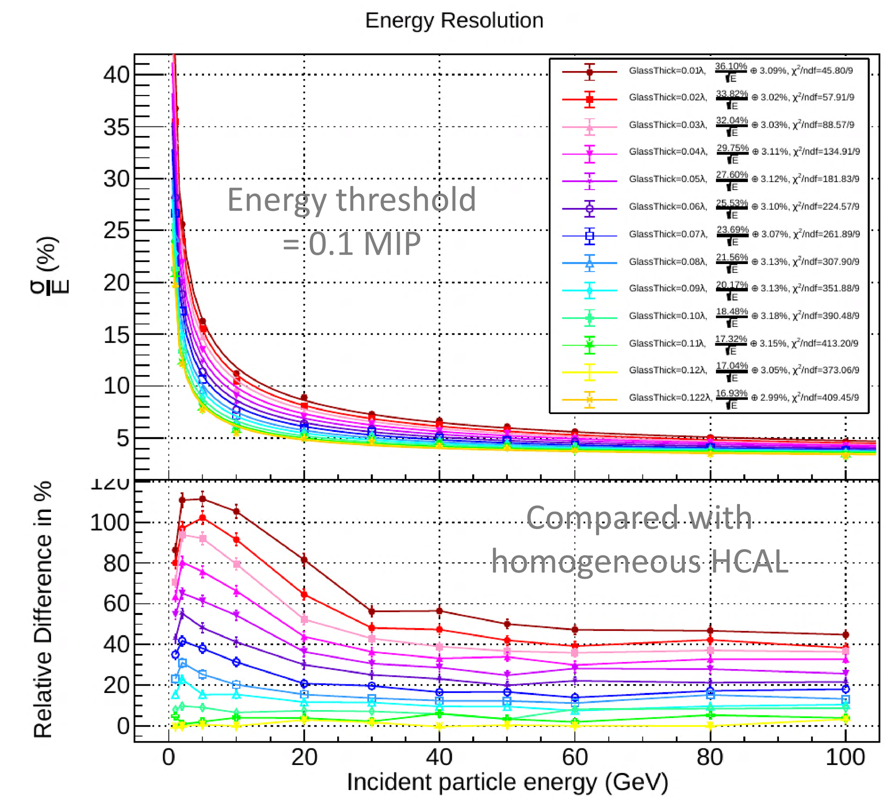
Note: Next study used a ideal geometry (semi-infinite) to avoid energy leakage.

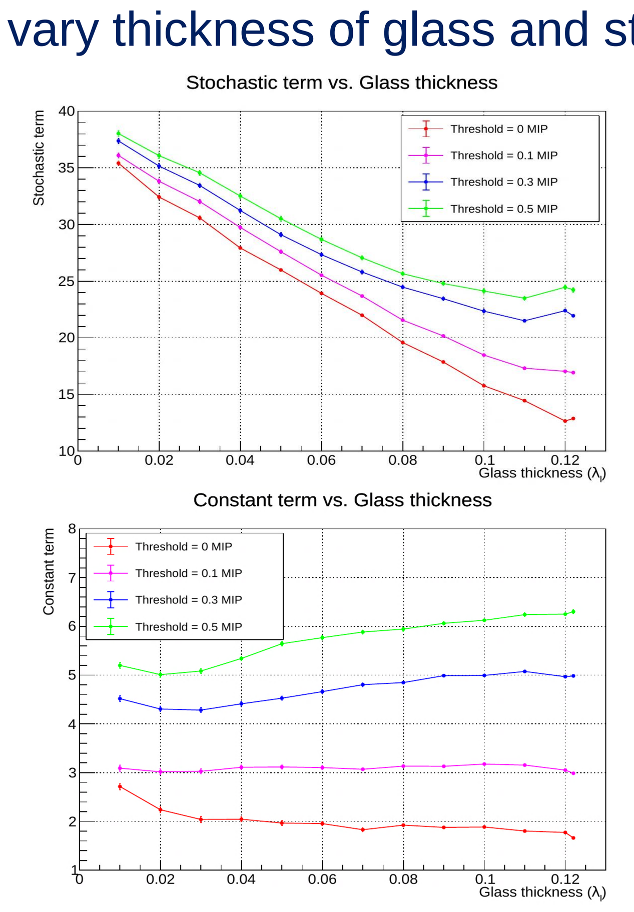


- Scintillating glass HCAL has better hadronic energy resolution, especially in low energy resolution
- The increase of density does not significantly improve the energy resolution

2. Hadronic energy resolution

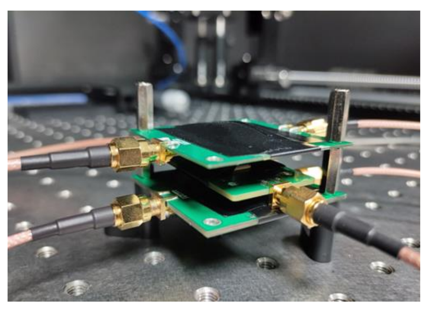
- Each layer thickness fixed with $\sim 0.12\lambda_I$, vary thickness of glass and steel

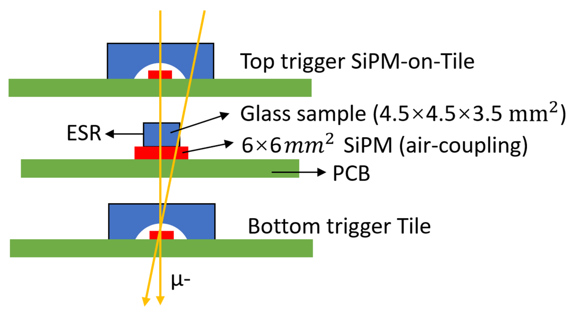


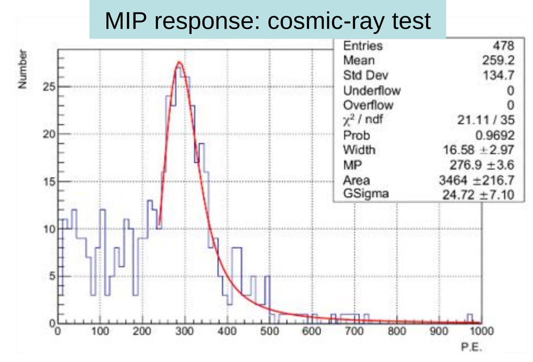


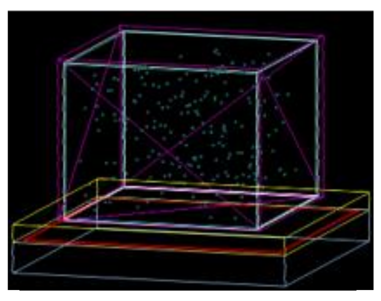
- Energy threshold has a significant impact on the energy resolution
  - Lower threshold would always be desirable for better resolution
- Better stochastic term with thicker scintillating glass
- The increase of glass thickness dose not significantly impact the constant term

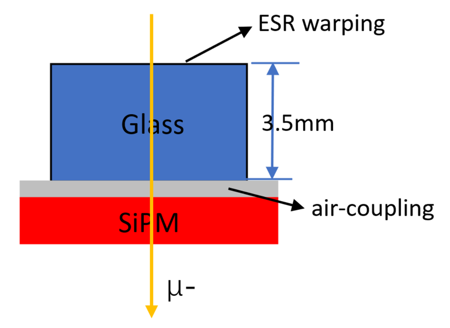
3. MIP response of detector unit

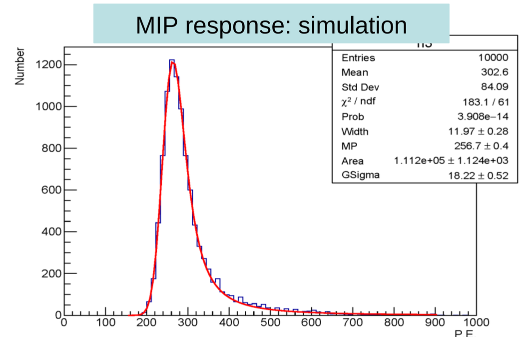






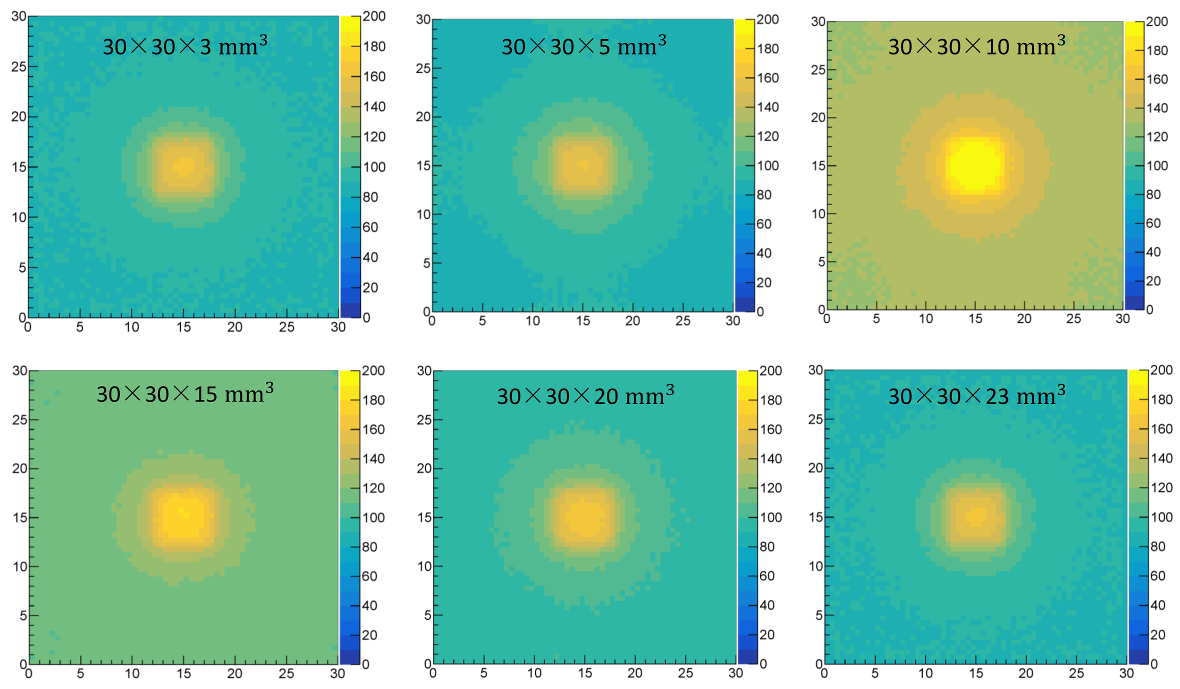


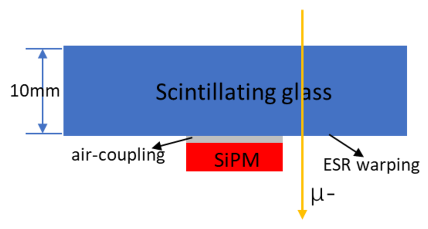




- MIP response in cosmic-ray experiment: 277 p.e./MIP
- MIP response in simulation: 257 p.e./MIP
- Simulation validated by measurements: reasonable consistency achieved

4. Projected performance of detector unit





Thickness (mm)	Average response	Non-uniformity $\left(\frac{max-min}{average}\right)$
3	65	1.1
5	106	0.67
10	149	0.47
15	127	0.53
20	112	0.63
23	104	0.71

- Assumption: larger tile properties remain the same as small tiles
- Considering response and uniformity, the optimal thickness is ~10mm
- Uniformity can be further optimized with new glass tile designs

5. Conclusions

- **A new high granularity HCAL concept with high-density scintillating glass tiles is proposed to further improve the energy resolution and the BMR.**
- **Compared with the plastic scintillator, scintillating glass HCAL with a higher energy sampling fraction has a better hadronic energy resolution.**
- **Thicker scintillating glass and lower energy thresholds have better energy resolution.**
- **The optical simulation for HCAL detector unit has been validated by cosmic-ray experiment.**
- **The results of simulation are used as a guide for the detector design and the R&D of scintillating glass materials.**