中国科学院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences

Progress on Glass Scintillator HCAL

Dejing Du

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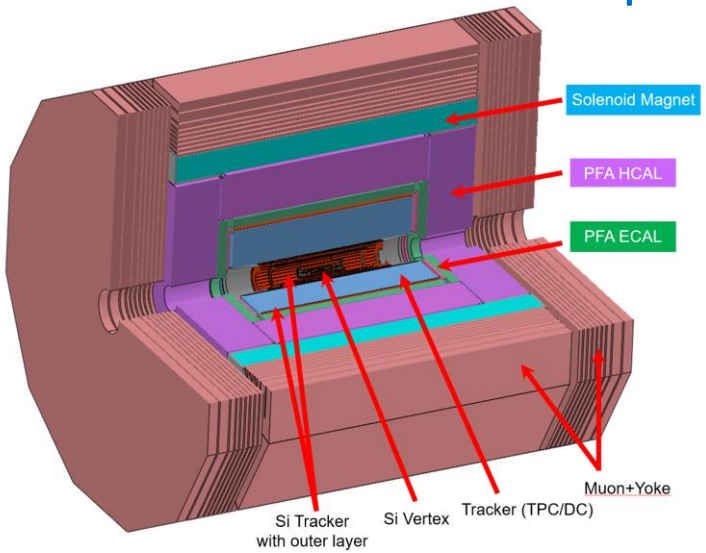
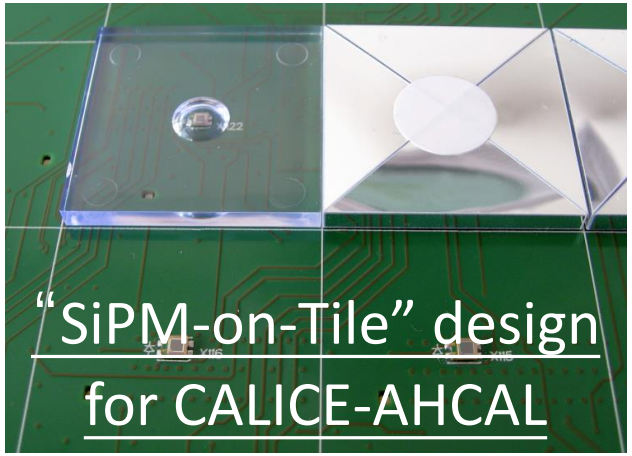
Glass Scintillator HCAL

The 4th Detector Concept



- PFA-oriented detector system: CEPC 4th concept design
  - Hadronic calorimeter (HCAL) with glass scintillator tiles
  - Requires glass scintillator with dense, bright, cost efficient
  - Expect better hadronic energy resolution → better BMR

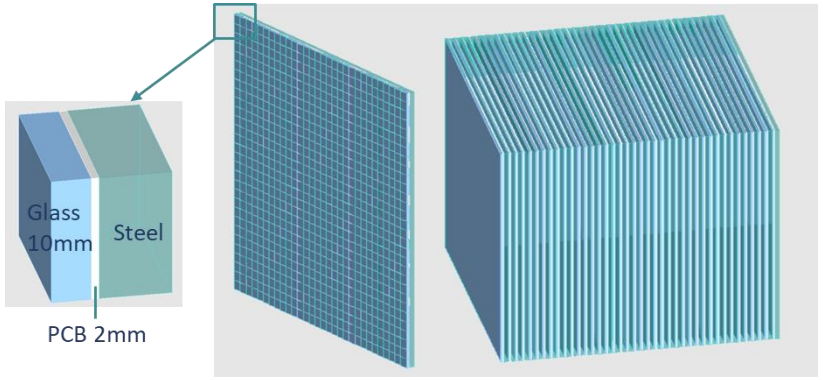
- R&D activities for glass scintillator HCAL
  - HCAL design, simulation studies and hardware developments
  - Hadronic energy resolution studies
  - PFA optimization and physics performance studies
  - Glass scintillator tiles: testing with cosmics/sources/beams
    - Key requirement: MIP response ~100 p.e. in 10 mm



Standalone Simulation setup

- GSHCAL geometry
  - Refer to Scintillator-Steel AHCAL (CEPC CDR baseline)
  - Replace plastic scintillator with glass scintillator
- Glass scintillator material
  - Components: Gd-B-Si-Ge-Ce^{3+}
  - Nuclear interaction length (NIL): 23.83 cm
  - MIP response: 7 MeV/cm
- GSHCAL nominal setup parameters:

GSHCAL module

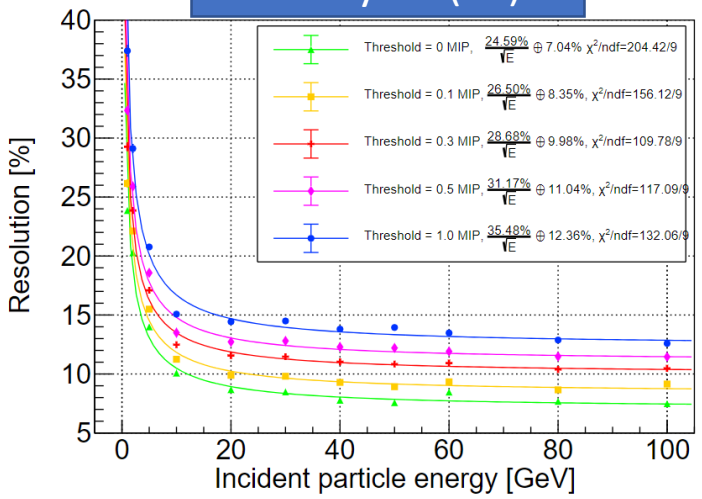


	Baseline (at CDR)	Ongoing (for TDR)
Total number of layers	**40**	**48**
Total NIL	**5 λ**	**6 λ**
Glass tile size	**40×40×10 mm³**	**40×40×10 mm³**
Glass density	**6 g/cm³**	**6 g/cm³**
Readout threshold	**0.1 MIP**	**0.1 MIP**

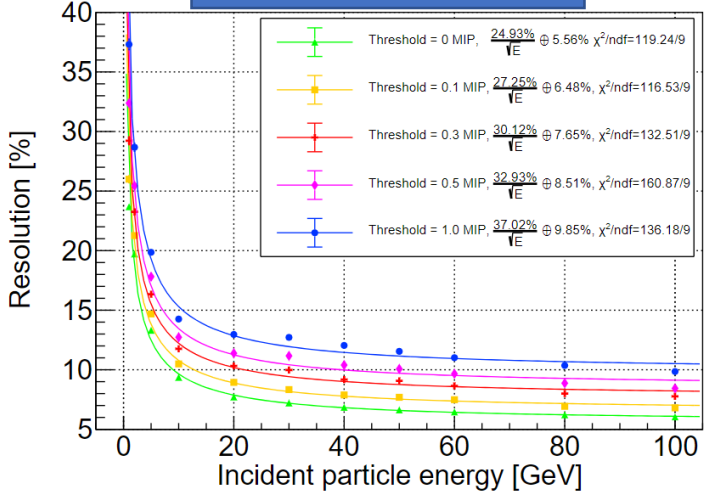
Impact of energy threshold

MC sample
1-100 GeV pi-

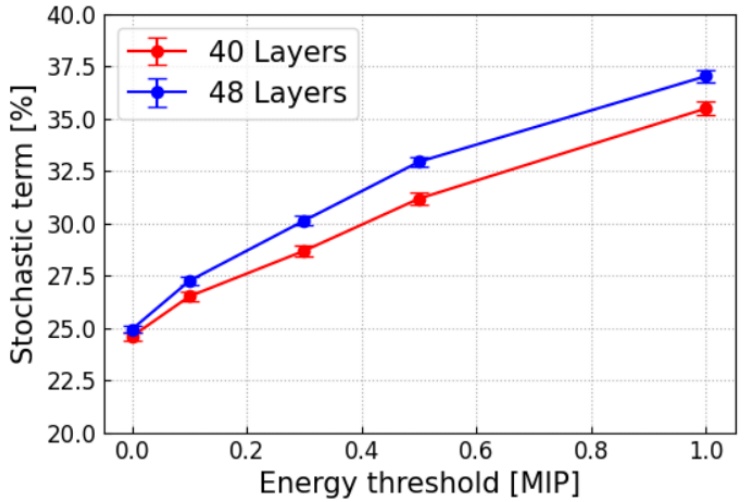
40 Layers (5λ)



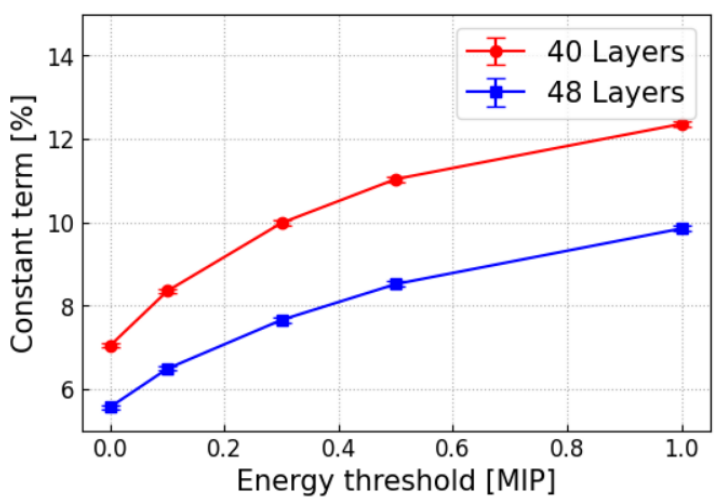
48 Layers (6λ)



Stochastic term vs. Ethr



Constant term vs. Ethr



- Vary energy threshold from 0 to 1 MIP
- Extract stochastic and constant terms in energy resolution

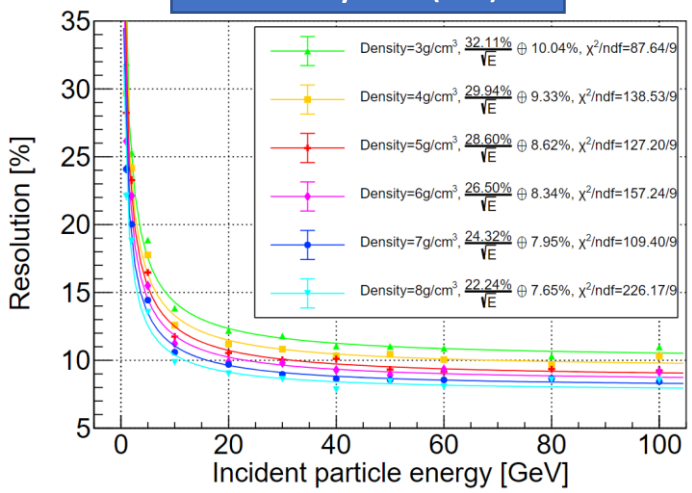
➢ The energy leakage of 40 Layers GSHCAL is significant, especially for the constant term

➢ Energy threshold has a significant impact on the energy resolution, and lower energy threshold would always be desirable for better energy resolution

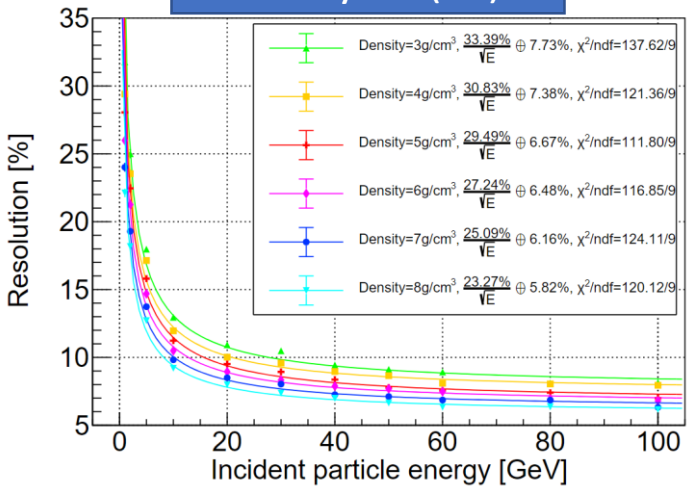
Impact of glass scintillator density

MC sample
1-100 GeV pi-

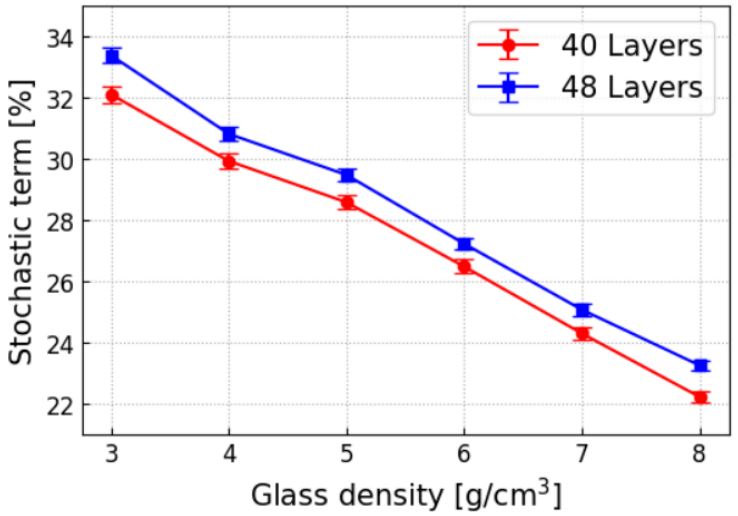
40 Layers (5λ)



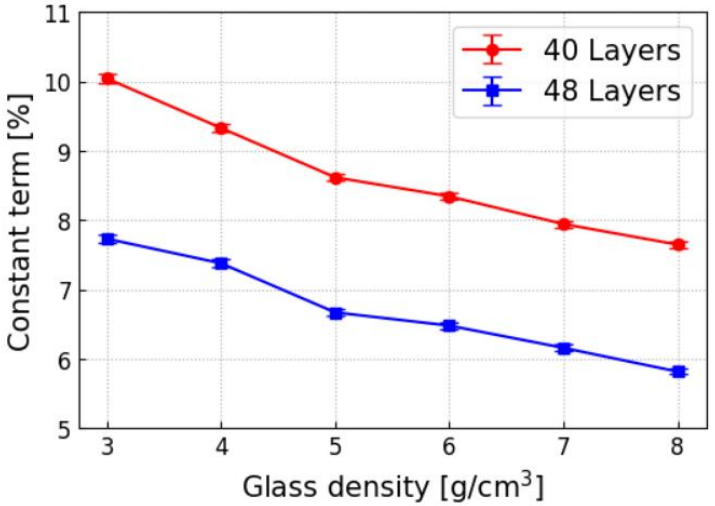
48 Layers (6λ)



Stochastic term vs. Density



Constant term vs. Density



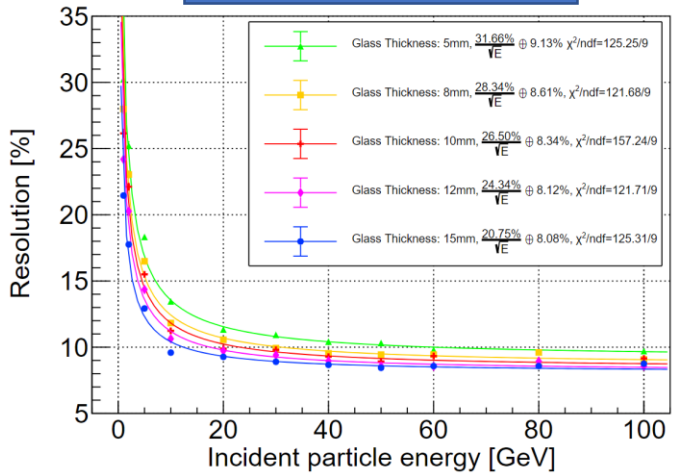
- Fixed NIL of each layer, vary glass density from 3 to 7 g/cm3
- Extract stochastic and constant terms in energy resolution

➢ Higher glass density can improve hadronic energy resolution and provide a more compact detector structure

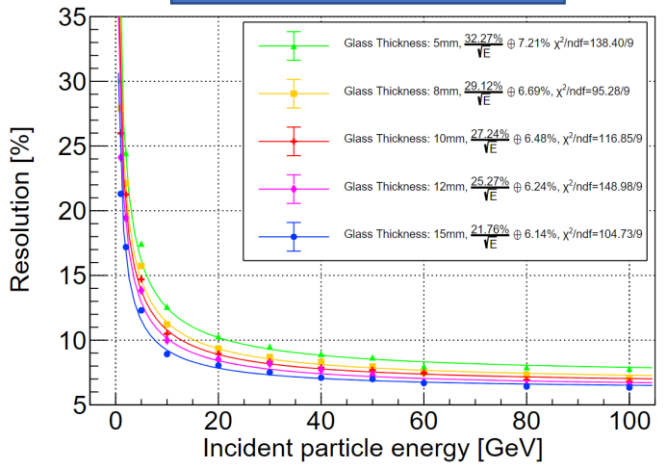
Impact of glass tile thickness

MC sample
1-100 GeV pi-

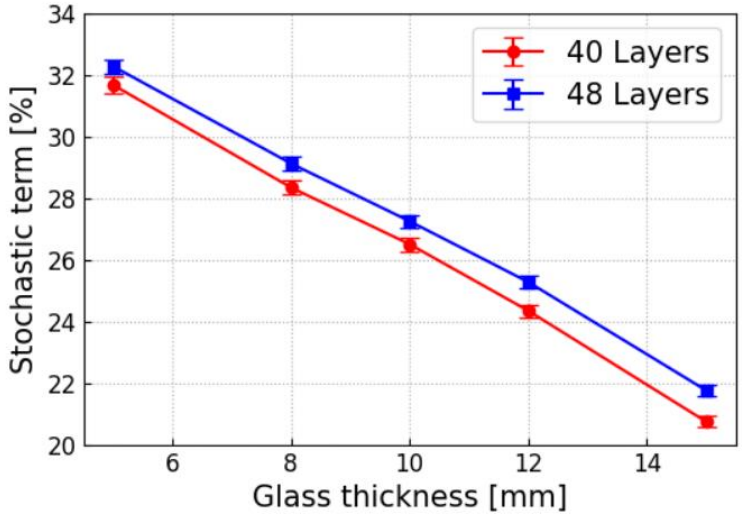
40 Layers (5λ)



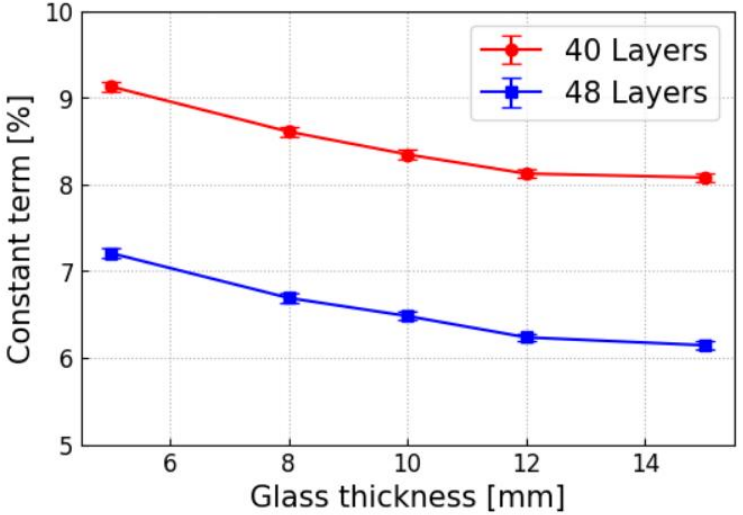
48 Layers (6λ)



Stochastic term vs. Thickness



Constant term vs. Thickness



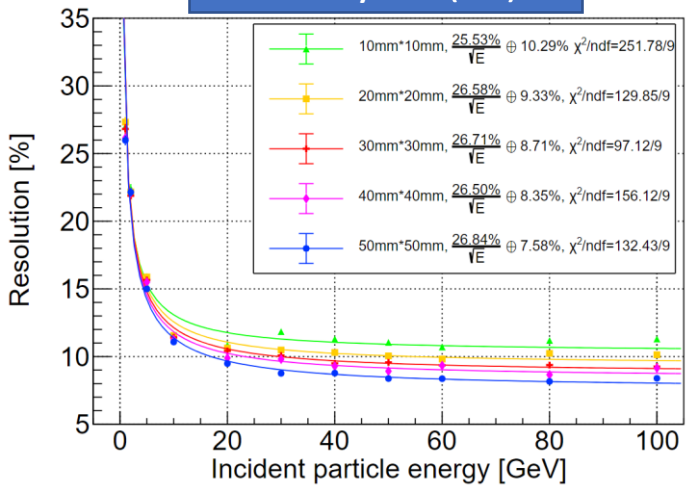
- Fixed NIL of each layer, vary glass tile thickness from 5 to 15 mm
- Extract stochastic and constant terms in energy resolution

➢ The hadronic energy resolution can be improved with thicker glass tiles, especially the stochastic term

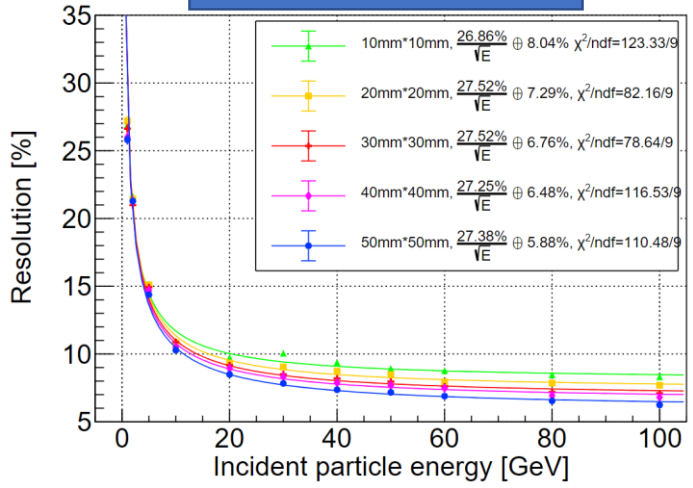
Impact of glass tile transverse size

MC sample
1-100 GeV pi-

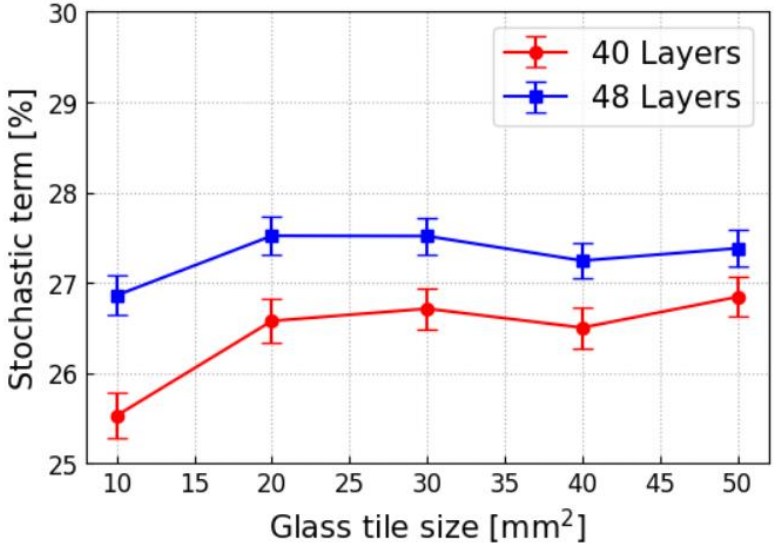
40 Layers (5λ)



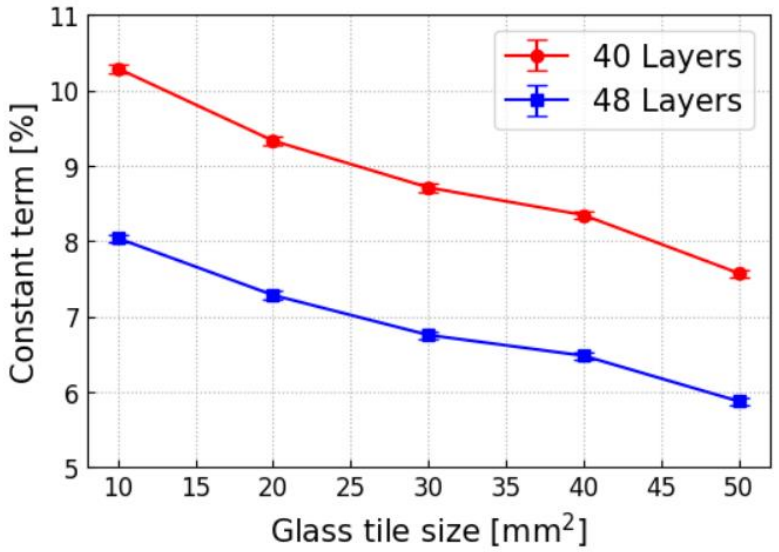
48 Layers (6λ)



Stochastic term vs. Tile size



Constant term vs. Tile size



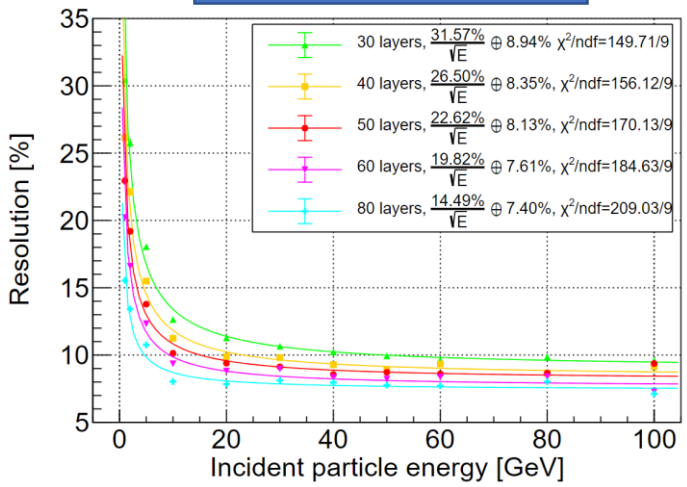
- Vary glass tile size from 10×10 to 50×50 mm2
- Extract stochastic and constant terms in energy resolution

➢ The

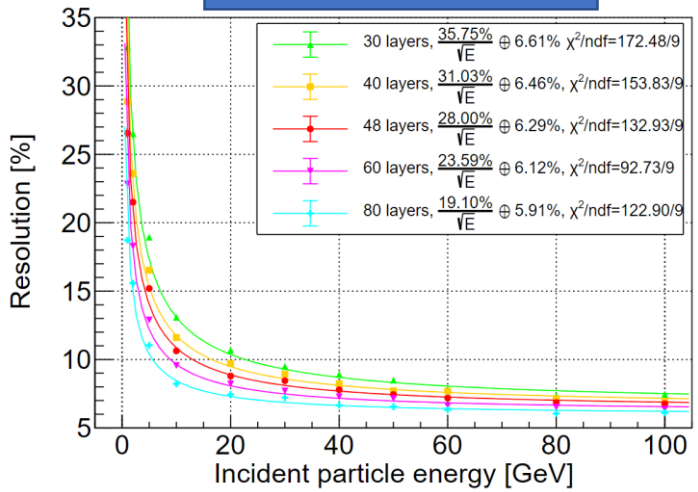
Impact of number of layers

MC sample
1-100 GeV pi-

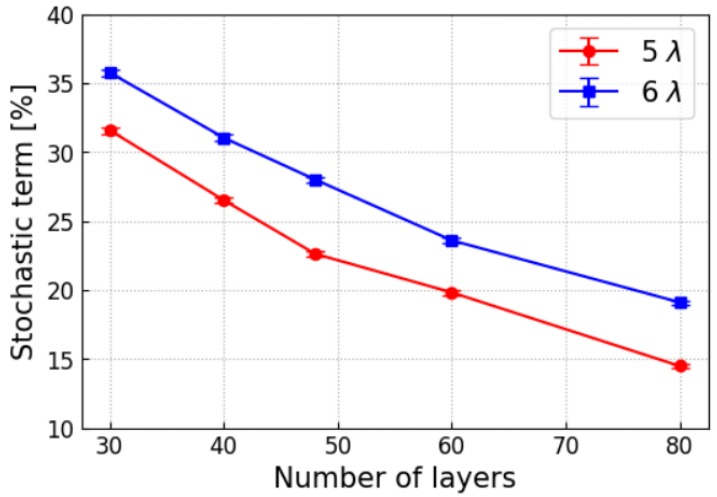
40 Layers (5λ)



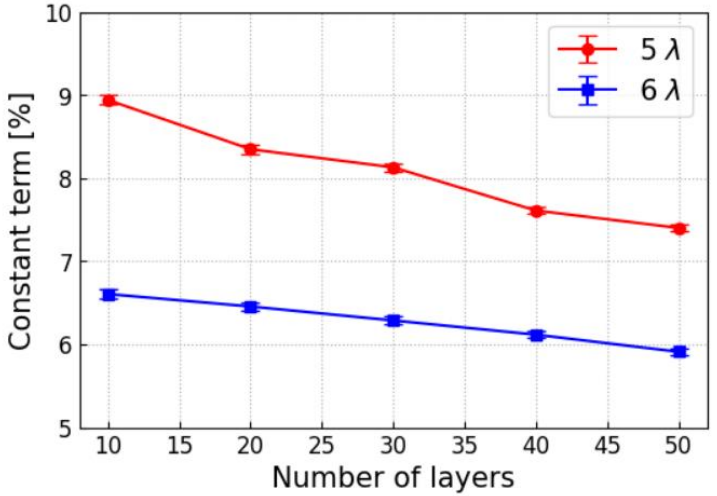
48 Layers (6λ)



Stochastic term vs. Layers



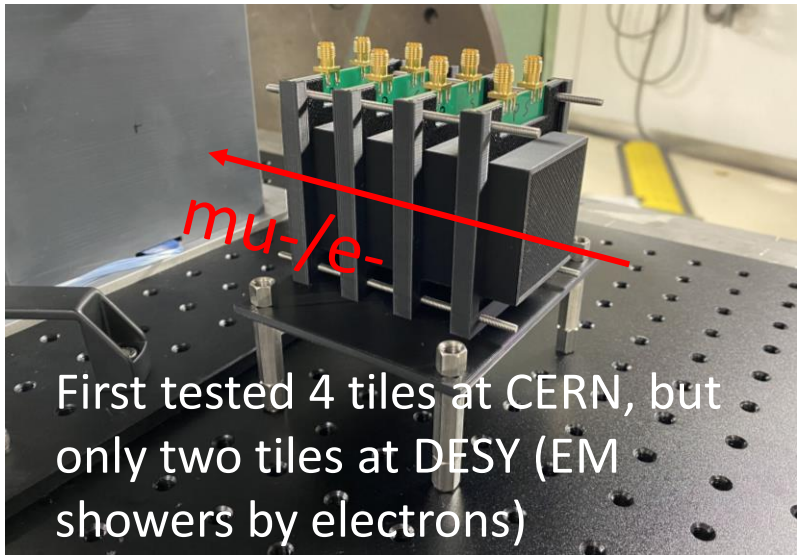
Constant term vs. Layers



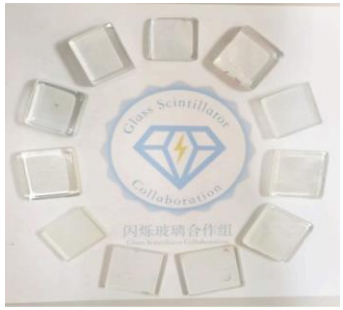
- Fixed total NIL and glass tile thickness, vary layers from 30 to 80
  - More layers → thinner steel thickness → larger sampling fraction
- Extract stochastic and constant terms in energy resolution

➢ The hadronic energy resolution can be improved with more sensitive layers, especially the stochastic term

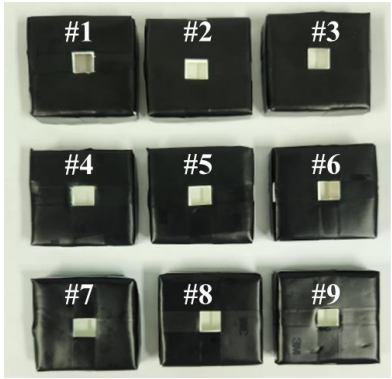
Beamtest setup of glass tiles



- First batch: 11 glass tiles with various tile dimensions successfully tested at CERN, using 10 GeV muon beam

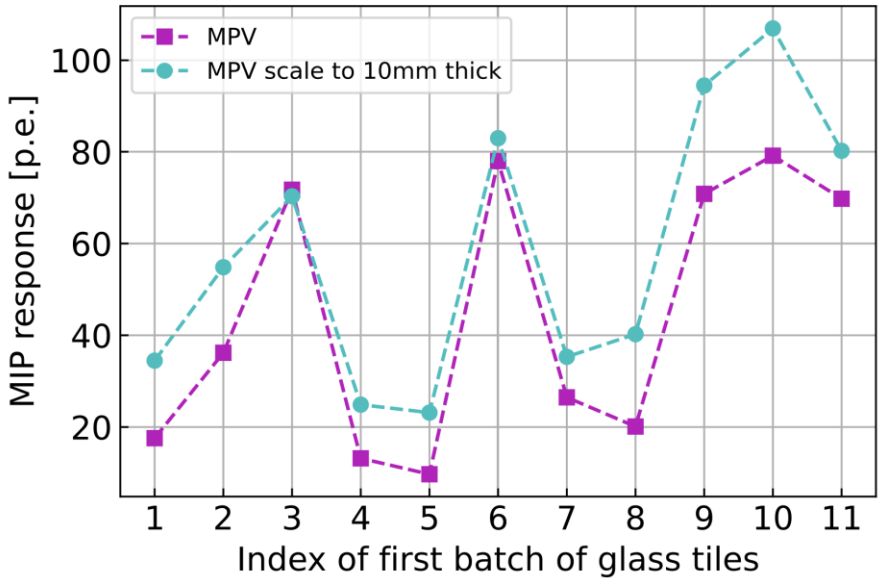


- Second batch: 9 glass tiles with standard tile dimensions (4×4×1 cm3) successfully tested at DESY, using 5 GeV electron beam

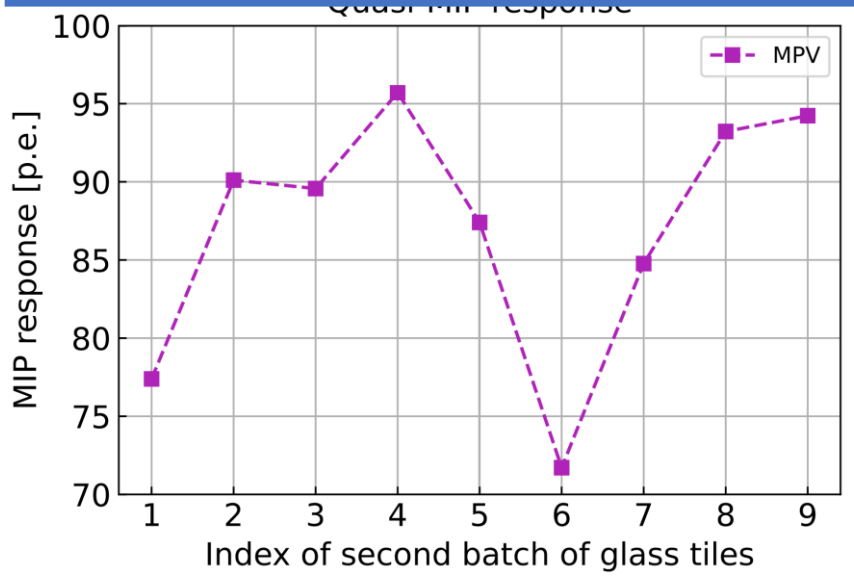


Beamtest results of glass tiles

MIP response for first batch of glass



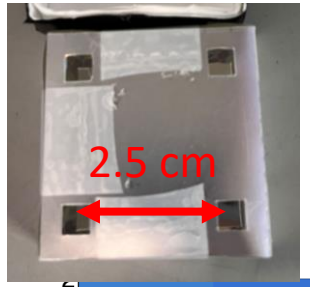
MIP response for second batch of glass



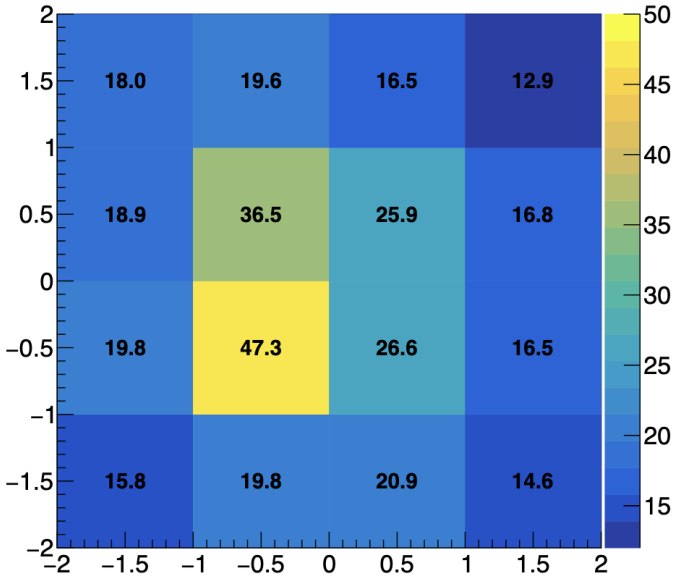
- First batch of tiles: typical MIP response of range of 10–79 p.e./MIP
  - Due to the different of glass components and production process
- Second batch of tiles: Quis-MIP response is 71–96 p.e./MIP, showed generally relatively good uniformity with the same batch

Beamtest results at DESY: tile uniformity

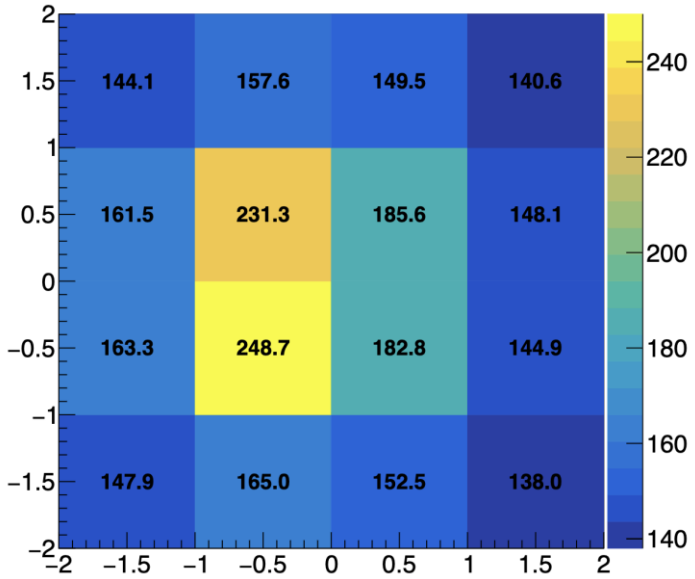
Tile coupled with one SiPM (6×6 mm^3):
cavity not yet implemented
for better response uniformity



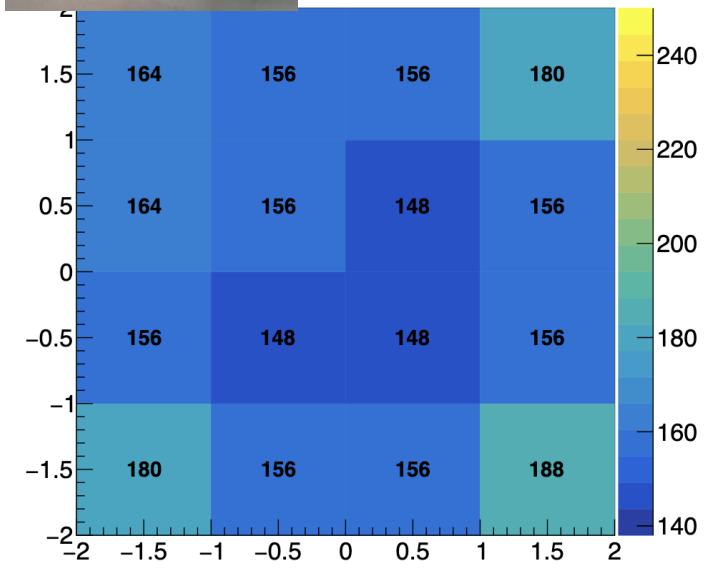
Tile coupled with 4 SiPMs (3×3 mm^3), to keep the same sensitive area



Glass (DESY#4)



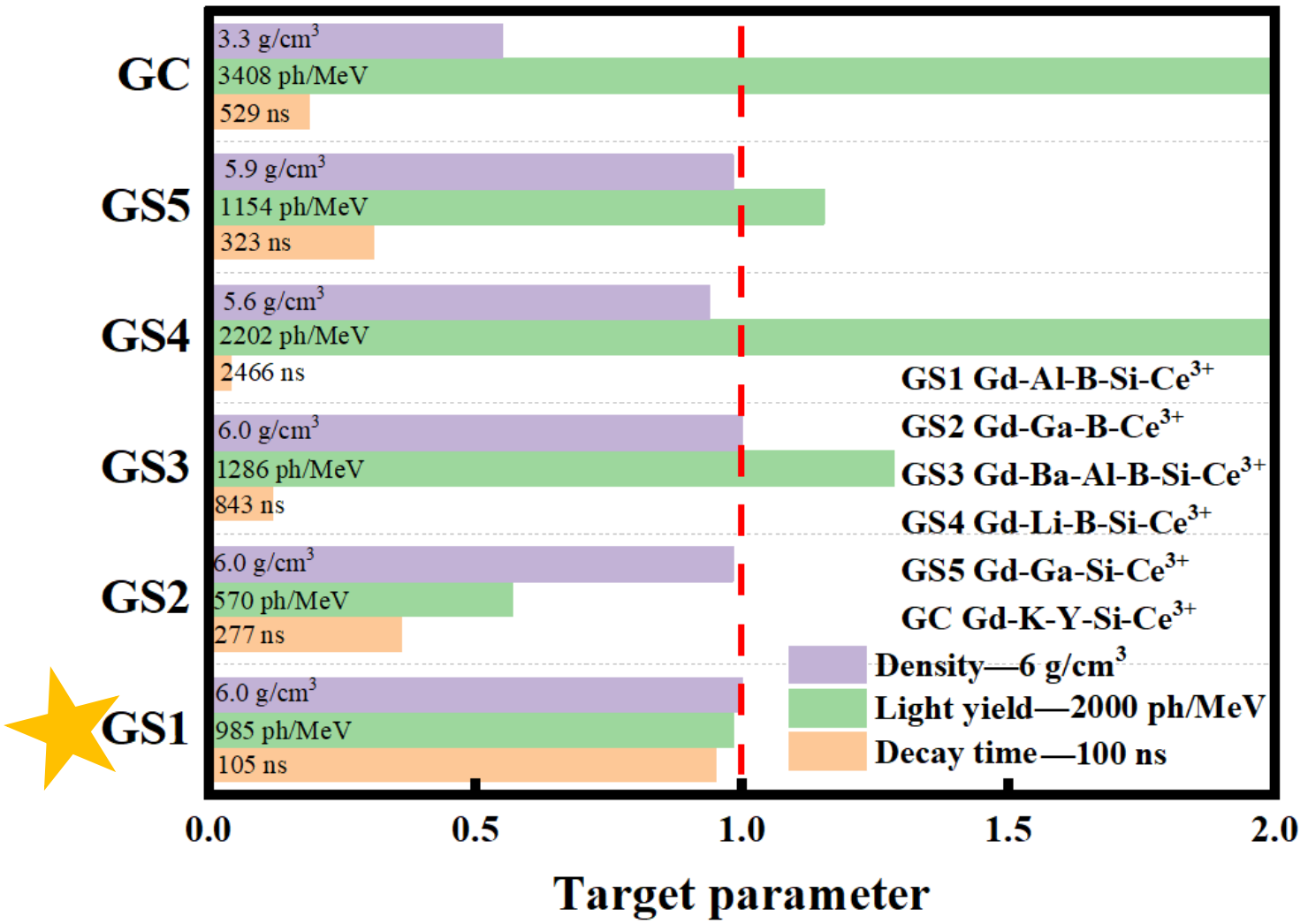
Plastic scintillator



Plastic scintillator

- 4 SiPMs can significantly improve tile non-uniformity at same total sensitive area
  - Glass tile uniformity need to be further optimized

Progress on R&D of glass scintillator material



- GS1 sample with best performance
  - Density: 6 g/cm3
  - Light yield: 985 ph/MeV
  - Decay time: 105 ns
  - Small size: 5×5×5 mm3
- Very promising to achieve the CEPC GSHCAL requirement
- The difficulty is to achieve such good performance with large size samples

Summary and plans

- Update the impacts of some key parameters to hadronic energy resolution at TDR setup
  - Energy threshold, glass density, tile thickness, tile transverse size, No. layers
- Beamtest results of glass tiles and R&D progress of glass material shows that the properties of glass scintillator is very close to our requirement

- Next plans
  - The improvement of constant term
  - Implement the digitization using real data in the simulation
  - Design optimization of glass tiles for optimal performance