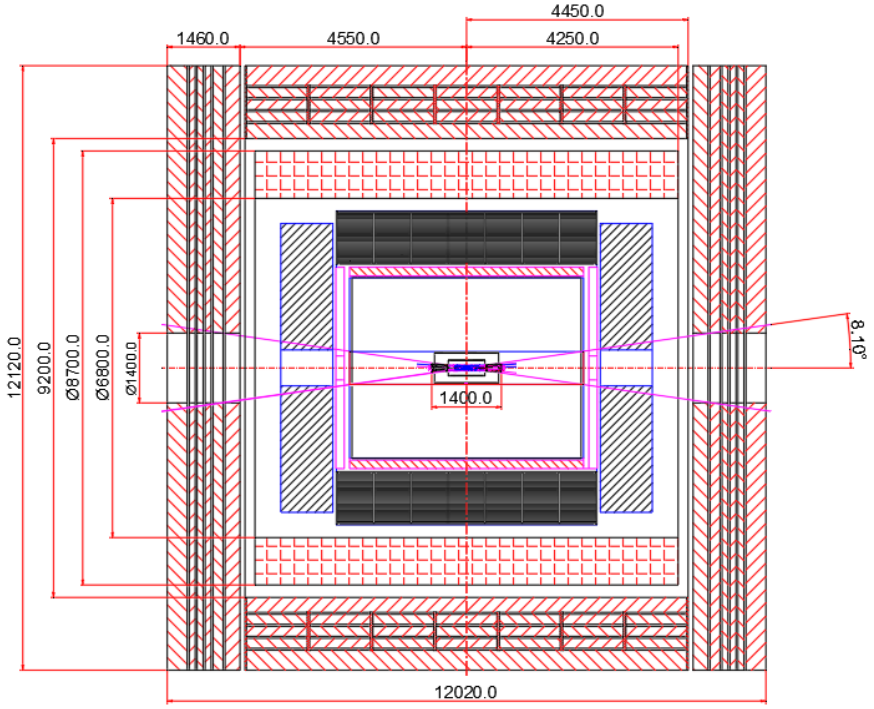
CEPC HCAL Mechanics: studies and discussions

Yong Liu (IHEP),
for the CEPC Calorimeter Group

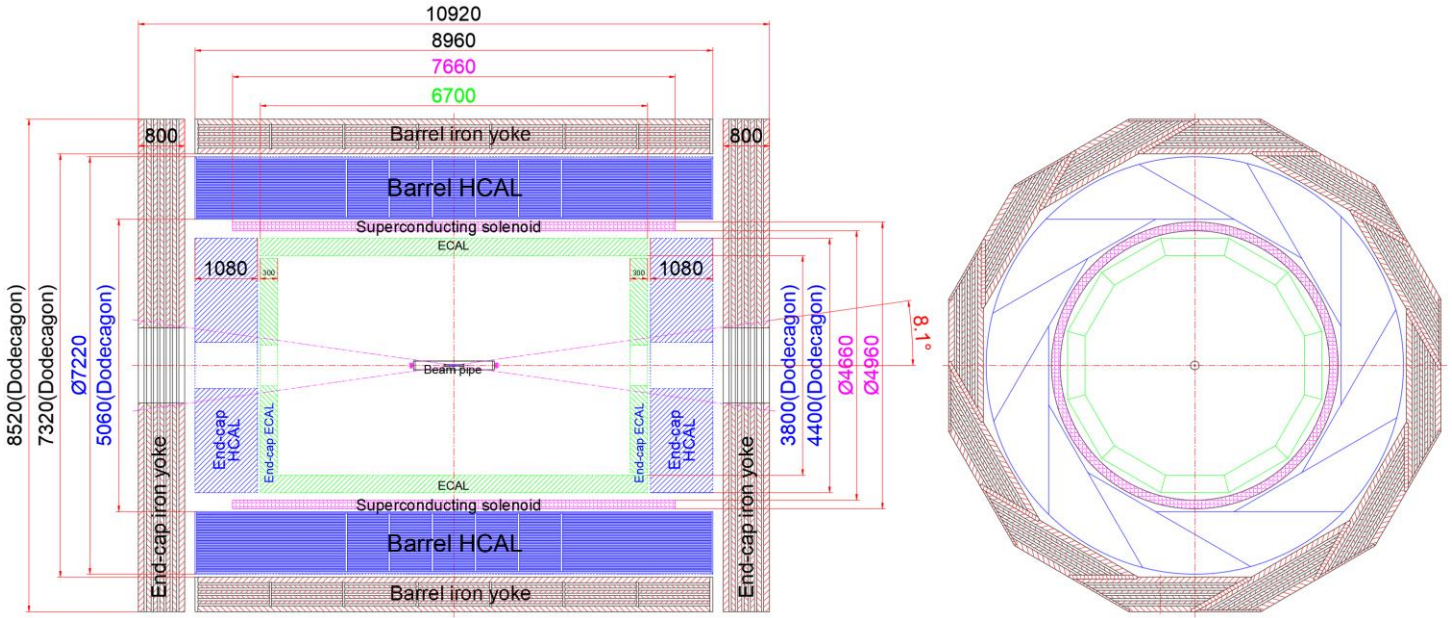
May 21, 2021

CEPC detector mechanics: reminder

- CEPC detector layout evolving: a few options proposed



A detector layout in the Mechanics Workshop 2020 by Quan Ji (IHEP)

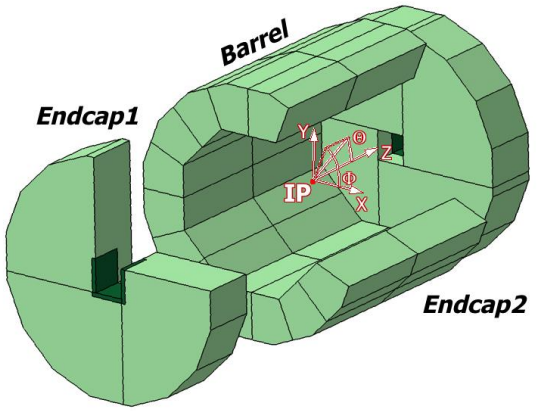


A new detector layout in the Yangzhou Joint Workshop 2021 by Quan Ji (IHEP)

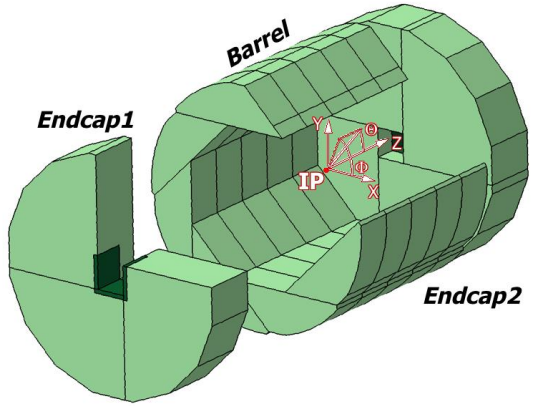
HCAL mechanics: context

- Mechanics for CEPC PFA-oriented Hadron Calorimeter
  - Two major designs at hand
  - Originated from ILD: ILD LOI (2010), ILC TDR Volume 4 (2013)
- Discussions within the CEPC calorimeter group meetings
  - Comparisons between the two designs: pros and cons
  - Focus on the barrel part
  - + mechanical engineer: Quan Ji (IHEP)
- Contents in this talk
  - A brief summary of the discussions
  - Highlights of existing simulation studies within CALICE Collab.

Layout 1: symmetric barrel

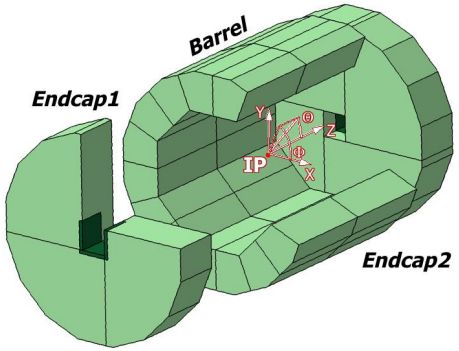


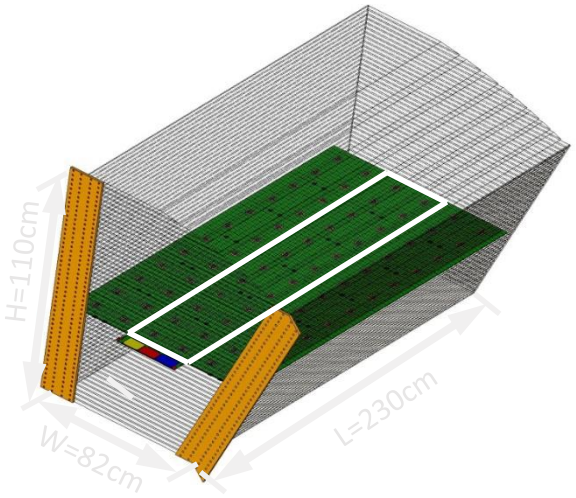
Layout 2: asymmetric barrel



HCAL layouts: comparison

HCAL Layout 1



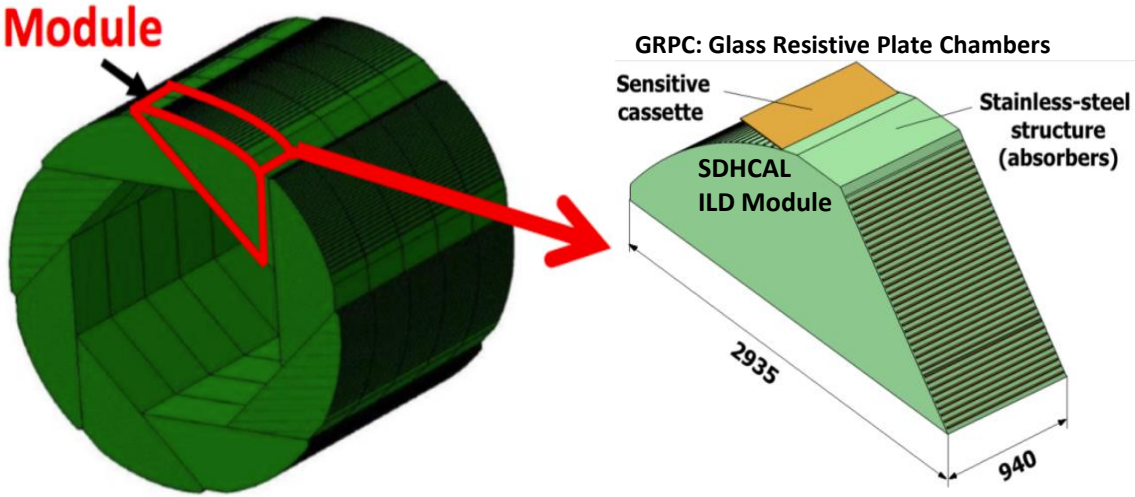


Z-axis: along beam direction

Symmetric Layout

+ Similar module sizes: friendly for QA/QC
− Projectile cracks from IP (z, φ): possible impacts to performance
− Difficulty for installation and maintenance from each side (along z)
  − Extra challenges for some designs of longer barrel HCAL (8-9m long); (Reminder: 4.7m for HCAL in ILD and CEPC CDR)

HCAL Layout 2

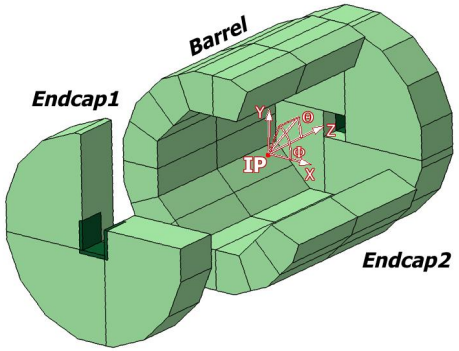


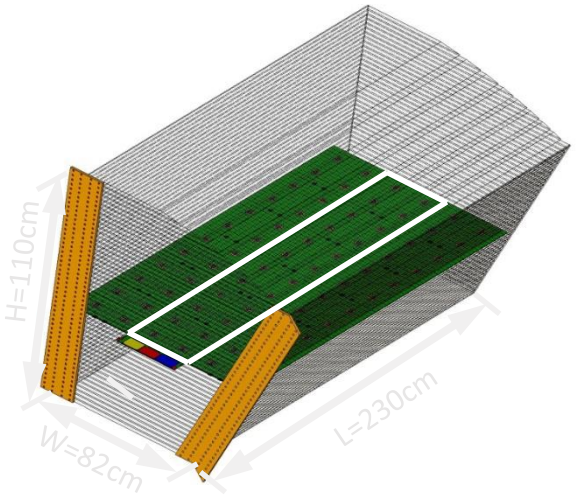
Asymmetric/spiral Layout

+ Avoid projectile cracks from IP along (z, φ)
+ Handy for installation and maintenance (along outer radius)
− Very different module sizes: challenges for QA/QC

HCAL layouts: comparison

HCAL Layout 1



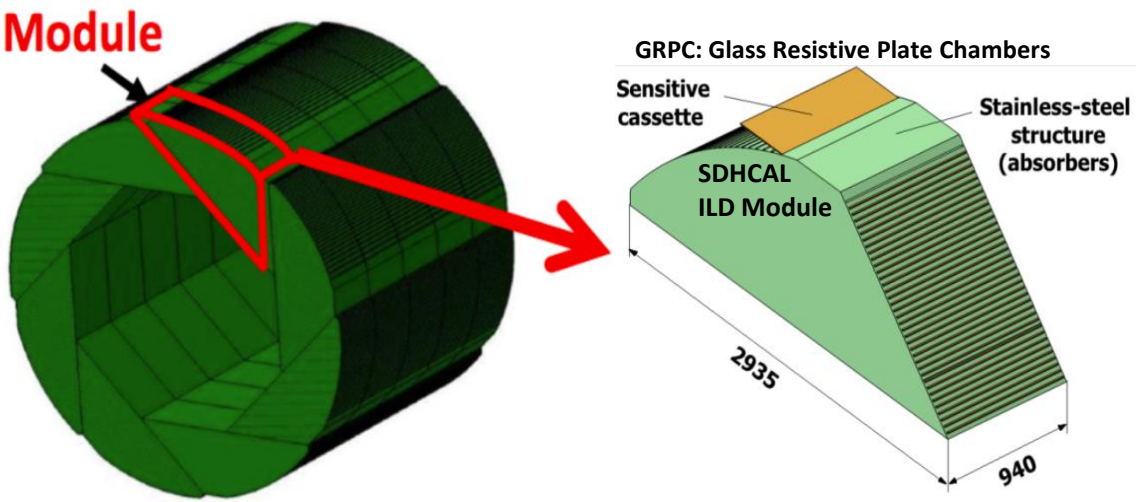


Z-axis: along beam direction

Symmetric Layout

+ Similar module sizes: friendly for QA/QC
– Projectile cracks from IP (z, φ): possible impacts to performance
– Difficulty for installation and maintenance from each side (along z)
  – Extra challenge for longer barrel HCAL designs (8-9m long); **ILD 4.7m**

HCAL Layout 2



Asymmetric/spiral Layout

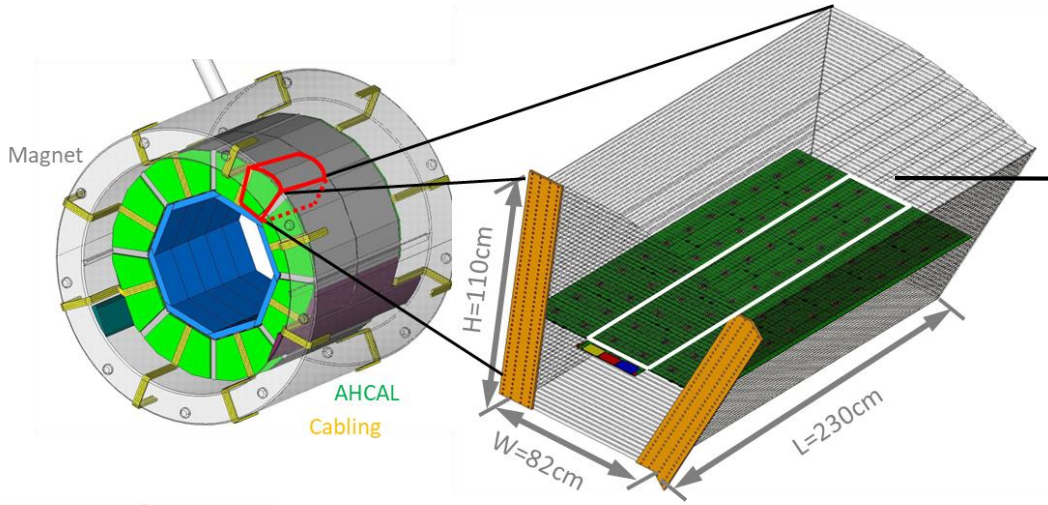
+ Avoid projectile cracks from IP along (z, φ)
+ Handy for installation and maintenance (along outer radius)
– Very different module sizes: challenges for QA/QC

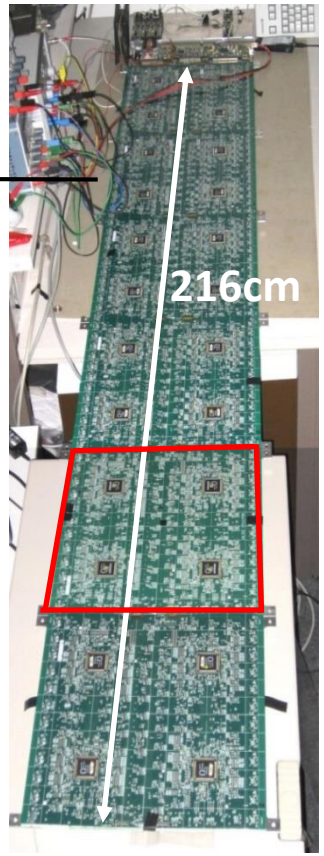
Technical challenges for both layouts:
(1) production/assembly of long modules: 2~4m in Layout 1; ~3m in Layout 2
(2) active cooling system and its integration with mechanics

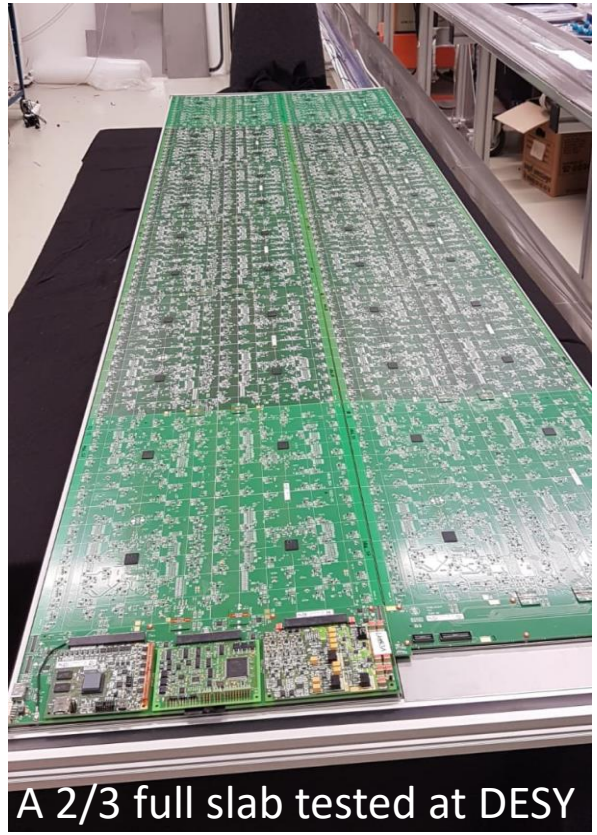
Ongoing R&D efforts to address the challenges (next pages)
(1) ~2m long AHCAL slabs (DESY); ~1x2m RPC+PCB (Lyon)
(2) Simulation studies of an active cooling system (SJTU)

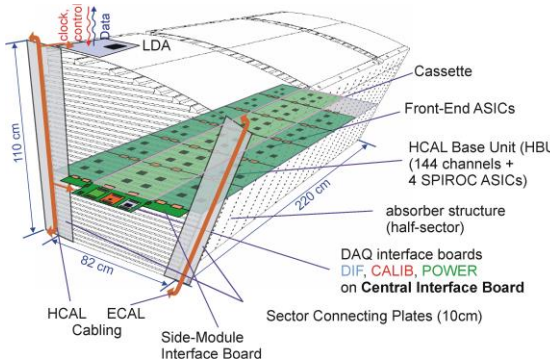
HCAL modules for the final detector

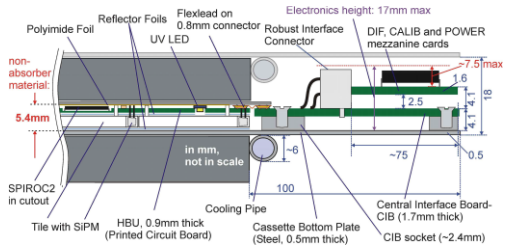
- Ongoing R&D efforts within CALICE to realise large-scale modules
  - Analog HCAL option: “SiPM-on-Tile” technology with steel plates
  - Efforts to test full-sized layers at DESY: aim for <u>1.1x2.2m² full slabs</u> at ILD

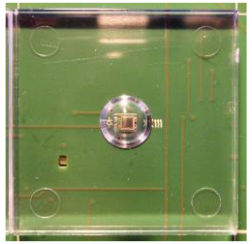






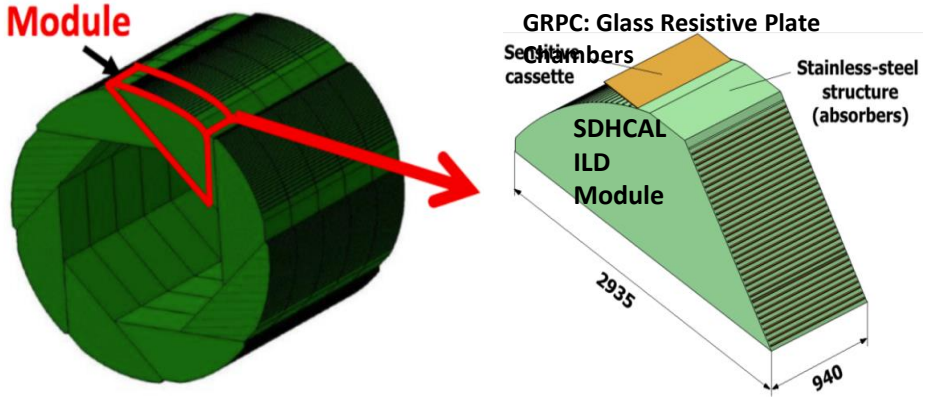


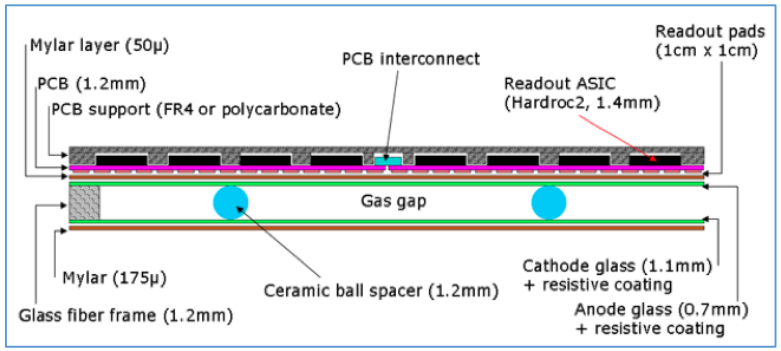




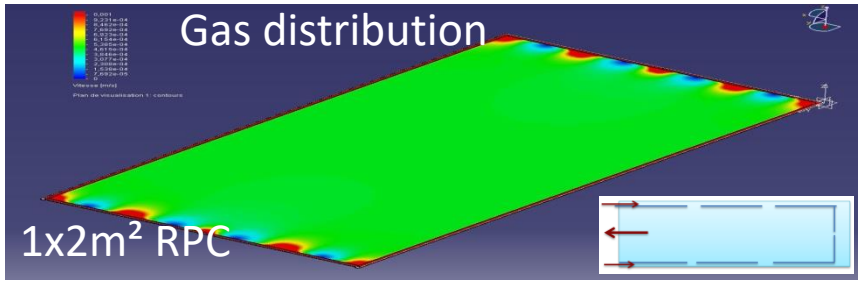
HCAL modules for the final detector

- Ongoing R&D efforts within CALICE to realise large-scale modules
  - Semi-digital HCAL option: large-scale RPC technology with steel plates
  - Efforts to build full-sized layers at Lyon: aim for full <u>1x3m² slabs</u>



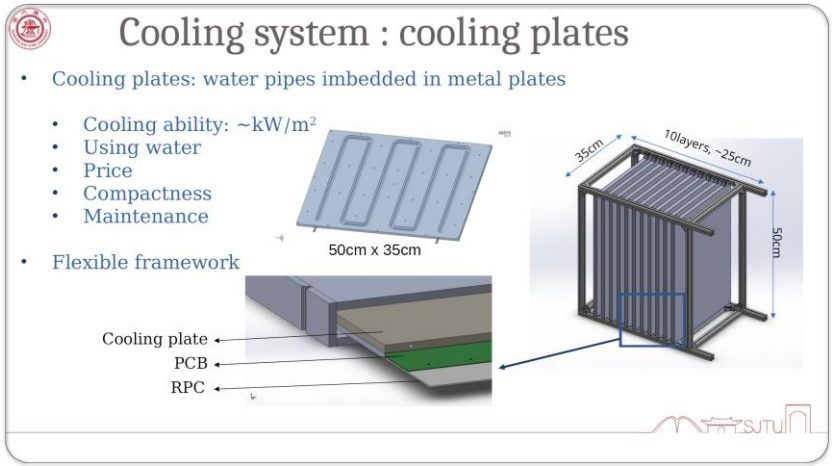


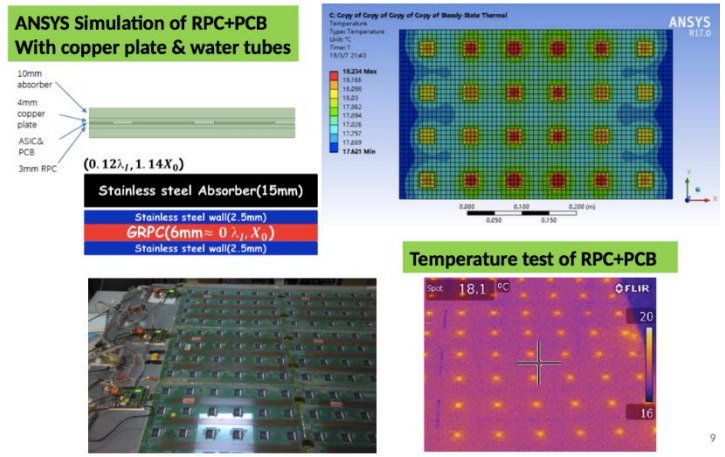
Assembled 1x2m² large RPC, 1x0.33m² PCBs



HCAL active cooling

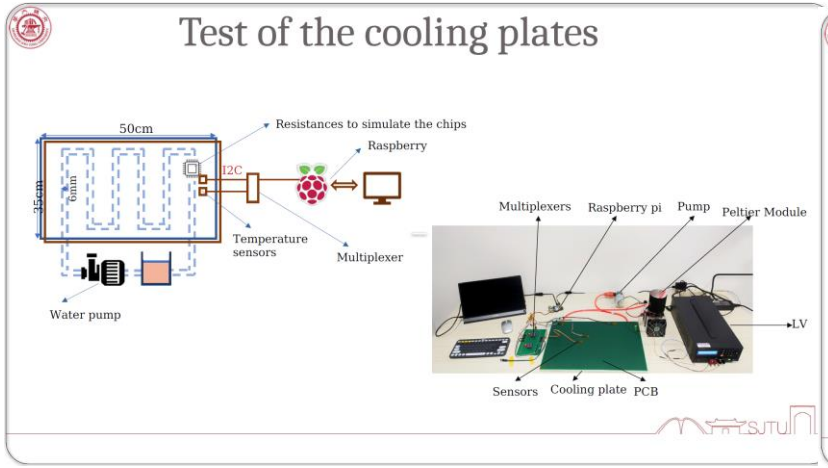
- Active cooling studies for SDHCAL at SJTU and Lyon
- We plan to further investigate for AHCAL: different ASICs (SPIROC2E) and lower granularity

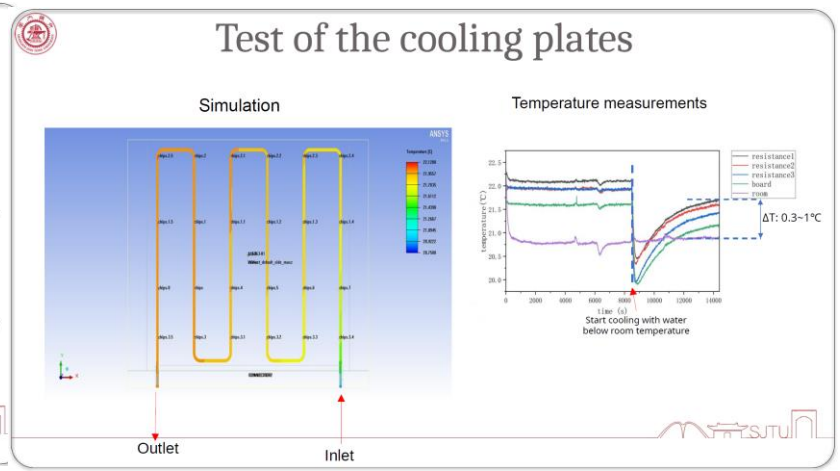


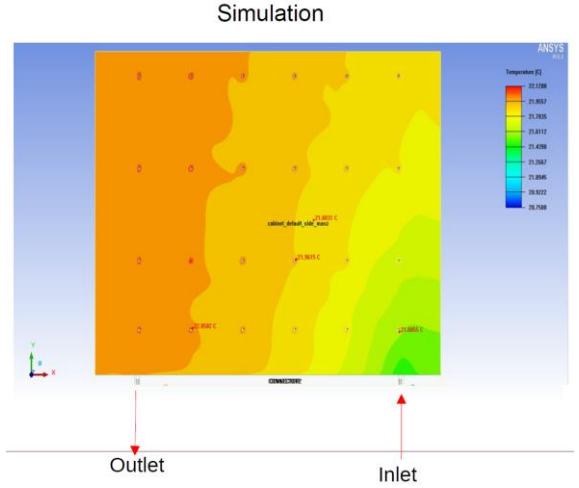


Synergies with the CEPC MOST-2 AHCAL prototype construction (40 layers, 72cmx72cm per layer)

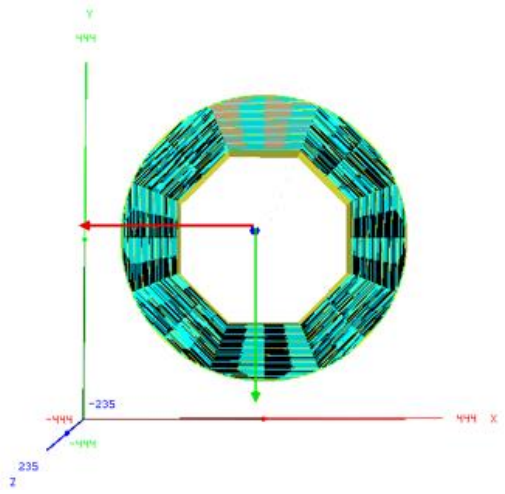
[SDHCAL Electronics, Gas Flow and Cooling](#) at [CALICE Collaboration Meeting Mar. 2021](#)

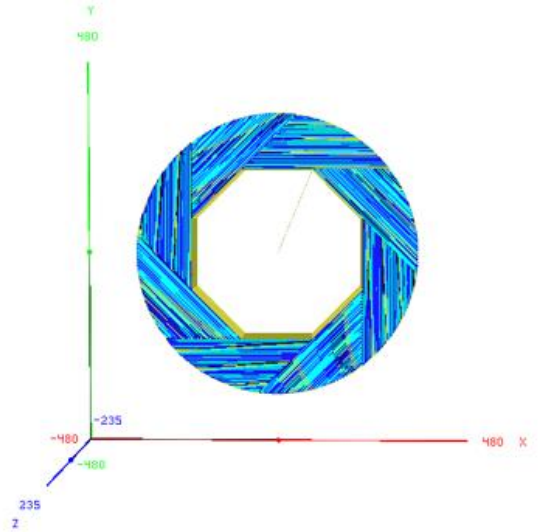




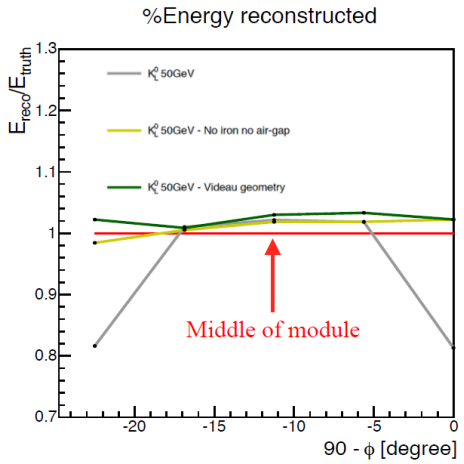


HCAL mechanics: simulation studies within CALICE

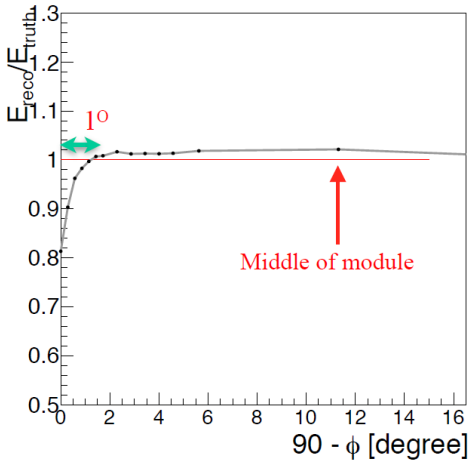




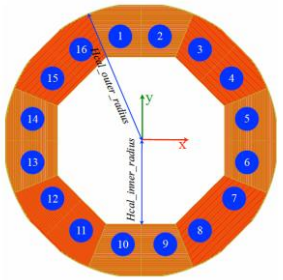
- Comparison of HCAL structures
  - Realistic symmetric structure with gaps
  - Ideal symmetric structure w/o iron and air gaps in φ
  - Asymmetric structure
- Loss of energy response and resolution due to cracks
- But this effect is negligible when integrating over all φ angles
  - Can be further mitigated by corrections

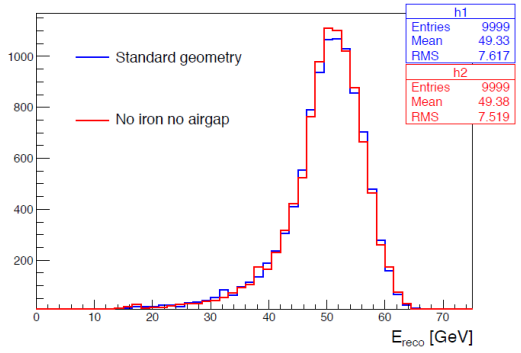


Finer phi steps



For single particle



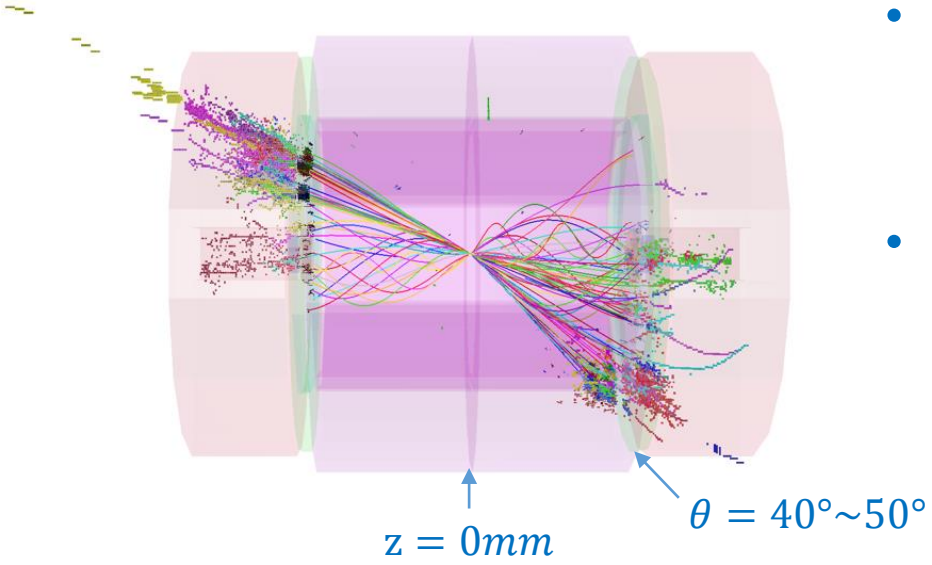


Fit Gaus90
Mean: 50.6938
Sigma: 5.07267
Res(Gaus90) = 10%

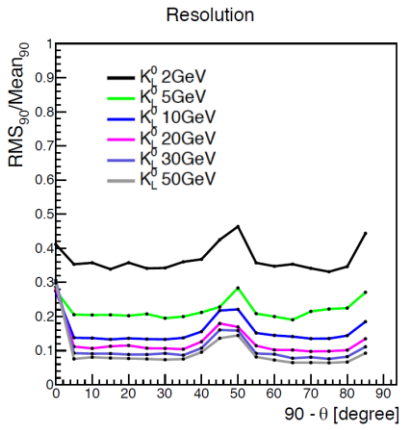
Mean: 50.7438
Sigma: 5.15704
Res(Gaus90) = 10.2 %

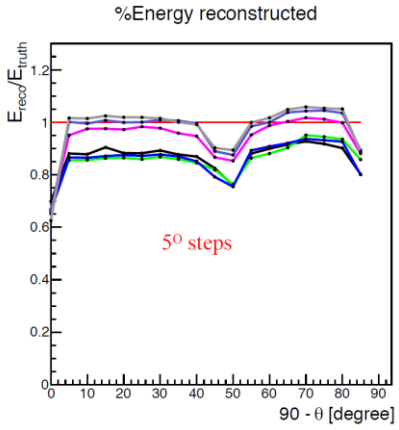
H.L. Tran, AHCAL optimisation using Pandora, LCWS2015

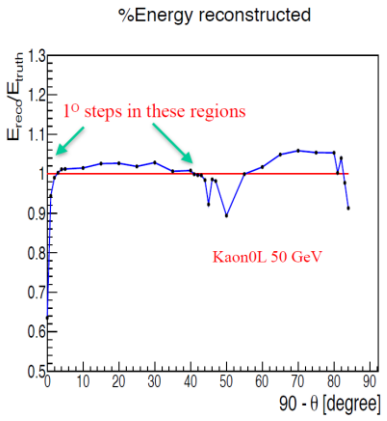
HCAL mechanics: simulation studies within CALICE



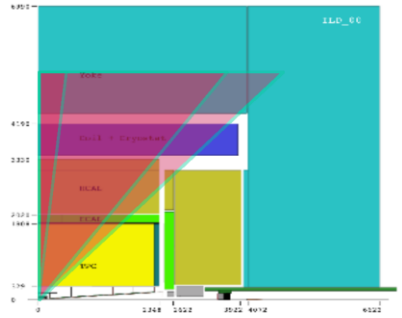
- Loss of energy response and resolution
  - At central iron plate ($z = 0$)
  - In transition region between barrel and endcap
- Can be mitigated by
  - Theta-dependent correction
  - Asymmetric barrel around the central plane ($z = 0$): e.g. staircase like

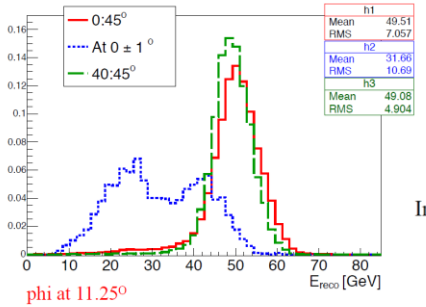


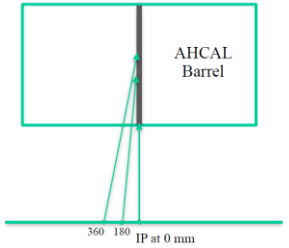




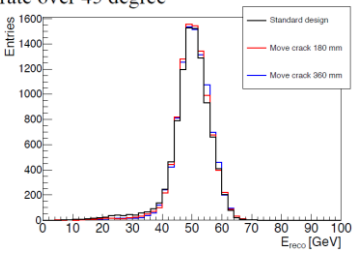
Effect of supporting structure (*r*,theta) plane







Integrate over 45 degree



➢Middle stave iron support seems to have stronger effect on energy reconstruction.

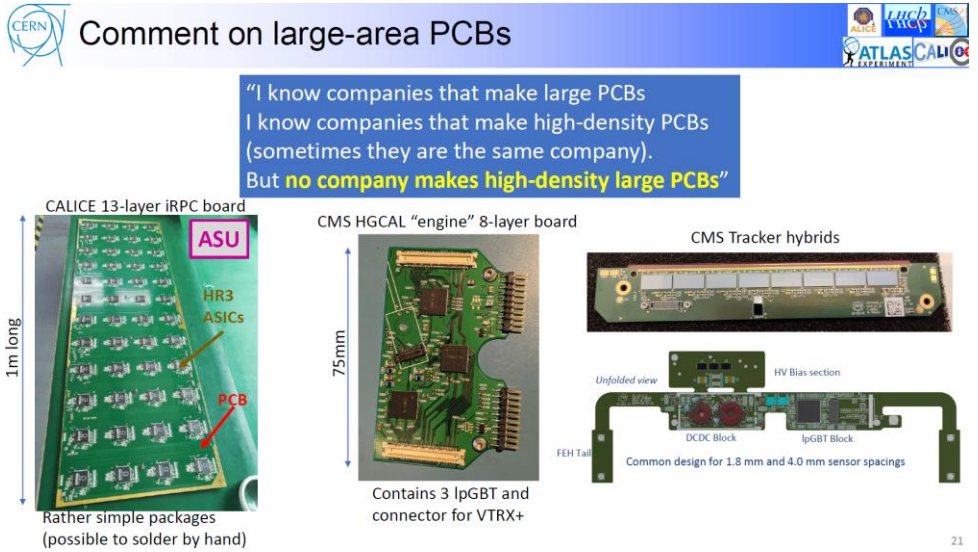
Possible improvements:

- Cluster's energy correction as a function of theta
- Or: Asymmetric design: middle stave iron support is not anymore "middle"

H.L. Tran, AHCAL optimisation using Pandora, LCWS2015

Summary

- Discussions on the HCAL mechanics
  - Symmetric vs. asymmetric layouts
- Ongoing R&D efforts to realise large modules
  - Within the CALICE collaboration
  - To address technical challenges
  - Essential inputs for the down-select process
- Active cooling: further studies for CEPC HCAL
  - Expertise from the SDHCAL team
  - Synergies with the CEPC MOST-2 AHCAL prototype development



Dave Barney, ECFA Detector R&D Roadmap Symposium of TF6 Calorimetry, Lessons learned: calorimeter upgrade R&D for HL-LHC & by CALICE