

CMS-HGCAL Progress

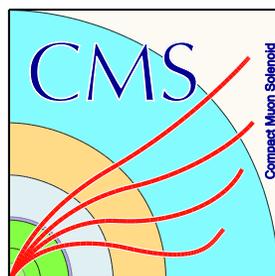
(with a focus on the contributions from IHEP team)

Yong Liu (IHEP)

on behalf of the CMS Collaboration

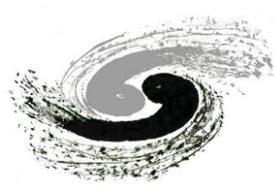
China LHC Physics Workshop, CCNU, Wuhan

Dec. 21, 2018

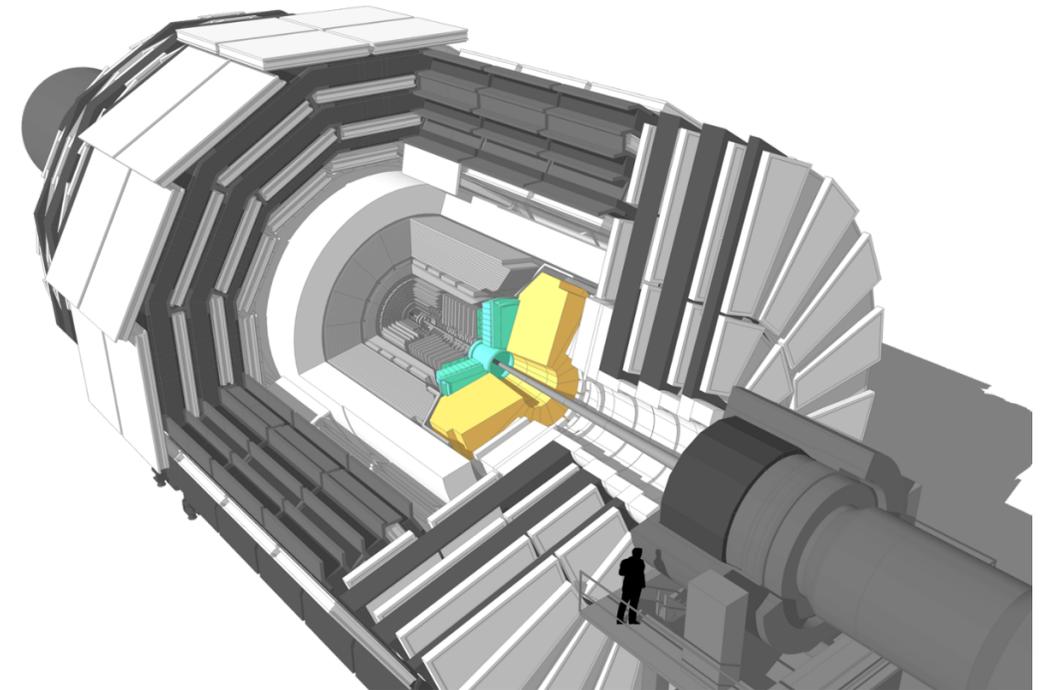
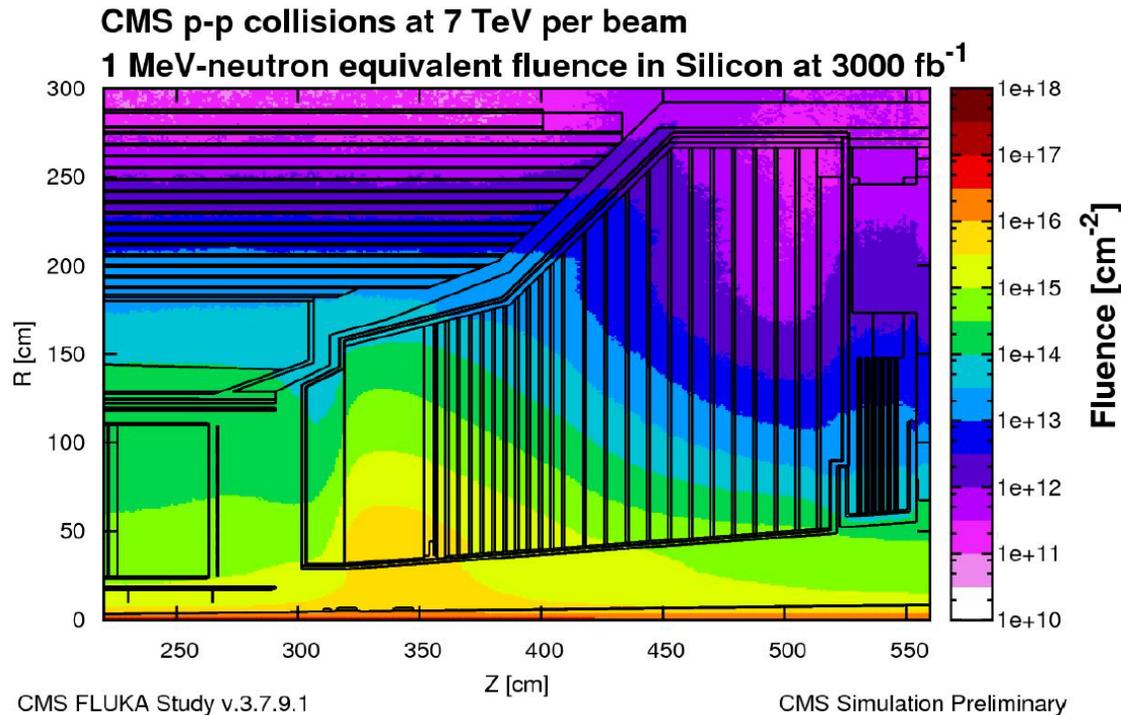


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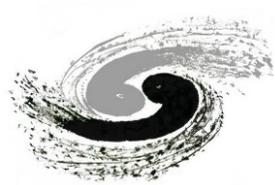


High-Granularity Calorimeter upgrade at CMS

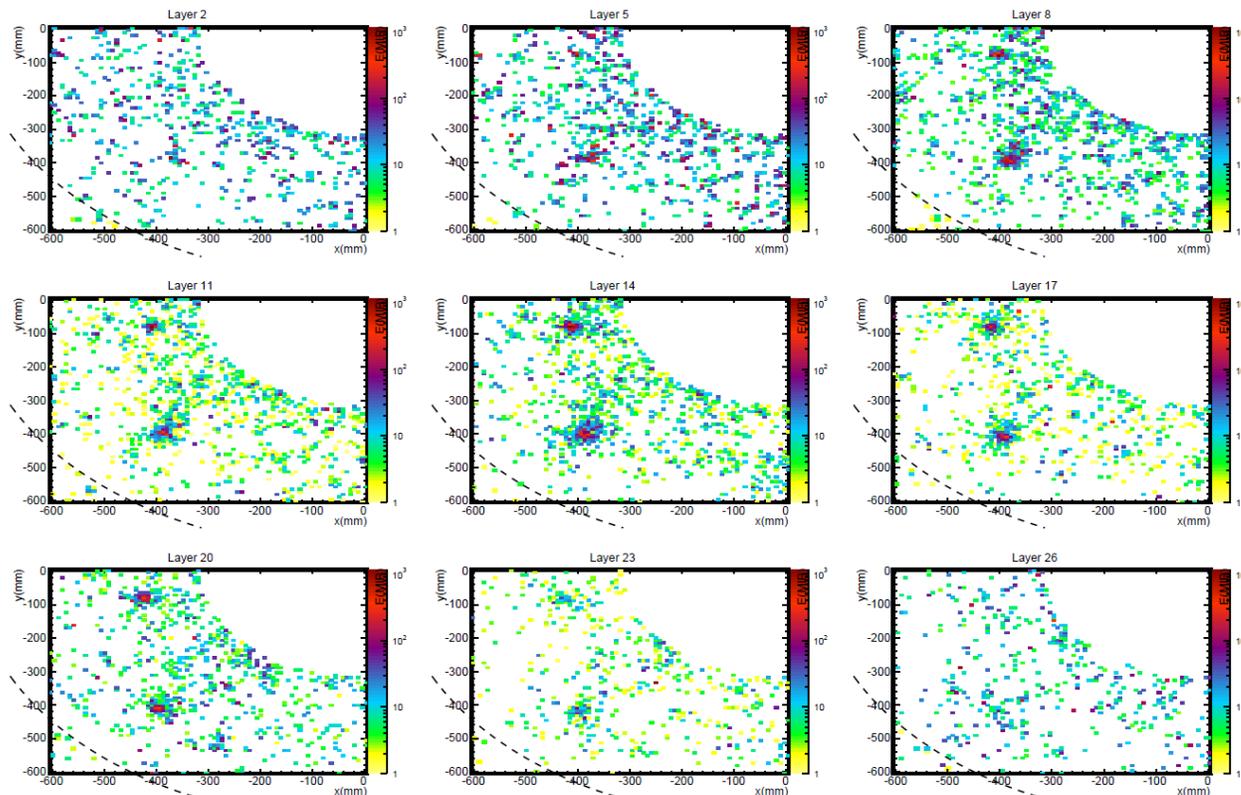


TDR released in Apr. 2018 (CMS-TDR-019)

- CMS endcap calorimeters: Phase-2 upgrade
 - Harsh environment at HL-LHC: high pile-up, high radiation level
 - Replace the existing CMS endcap calorimeters
 - Construct a high granularity calorimeter (HGCal)



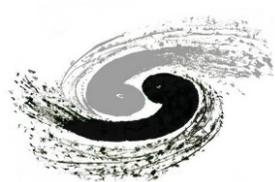
Why high-granularity calorimeter?



A VBF jet (720 GeV) and a photon (175 GeV) in a VBF $H \rightarrow \gamma\gamma$ event

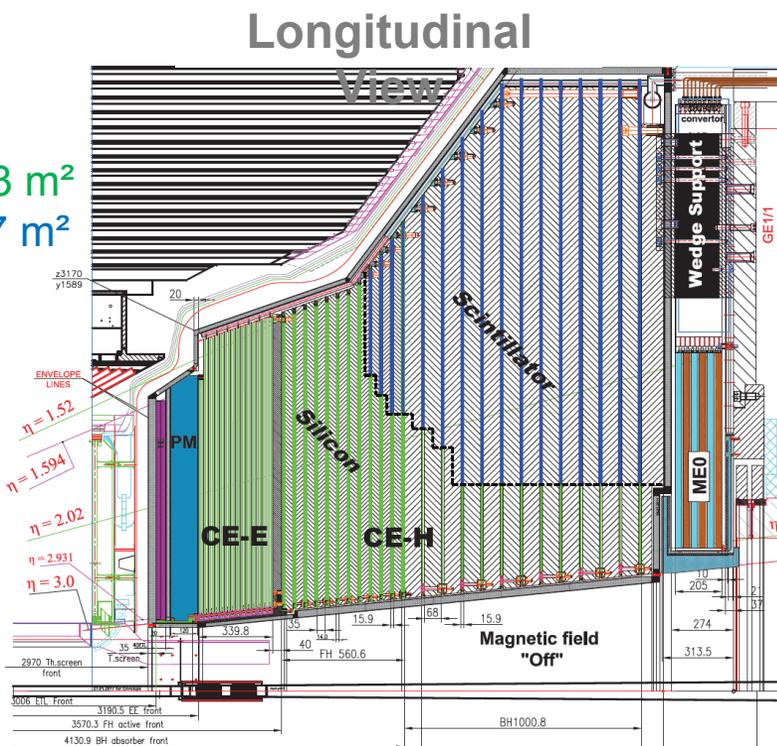
Including a mean pileup of 200 interactions per bunch crossing (i.e. HL-LHC)

- Unprecedented transverse and longitudinal segmentation
- Resolve EM and hadronic showers in high pile-up environment (HL-LHC)

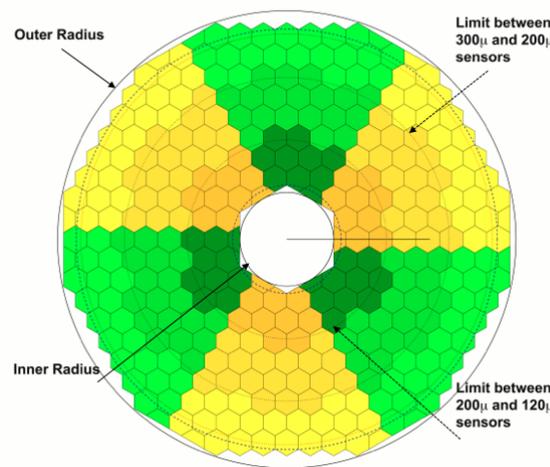


HGCAL overview

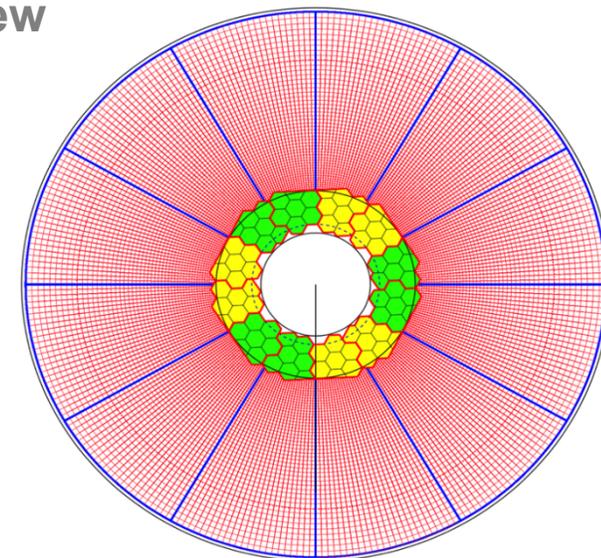
Si-sensors: 583 m²
Scintillator: 487 m²



Transverse View



CE-E 9th layer

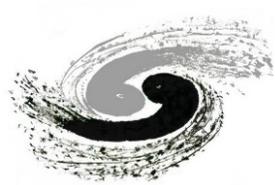


CE-H 22nd layer

- Silicon-only layers
 - 3 types of silicon sensors: 120, 200, 300 µm thick
- Mixed layers: silicon and scintillator-SiPMs
 - Boundary optimized for radiation tolerance

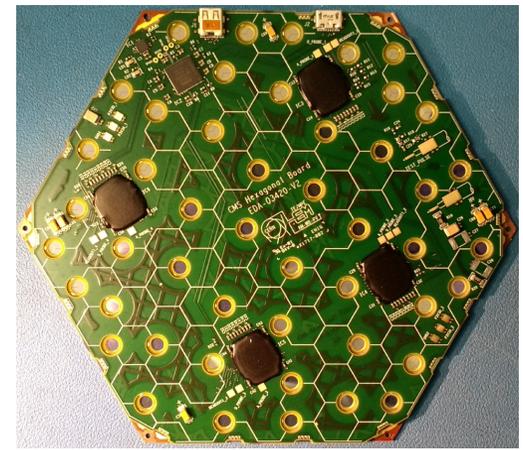
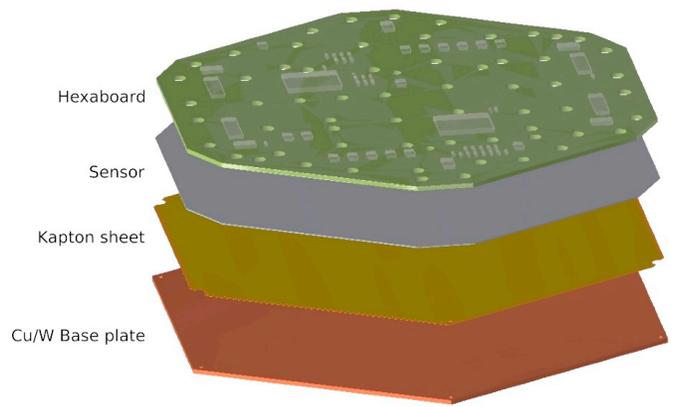
Active thickness (µm)	Cell size (cm ²)	Cell capacitance (pF)	Bulk polarity	Expected range of fluence (×10 ¹⁵ n _{eq} /cm ²)	Number of wafers	Number of partial wafers
300	1.18	45	p / (n)	0.1–0.5	13 164	1284
200	1.18	65	p	0.5–2.5	8712	144
120	0.52	50	p	2–7	3000	324
Total:					24 876	1752

~25k 8-inch modules in total



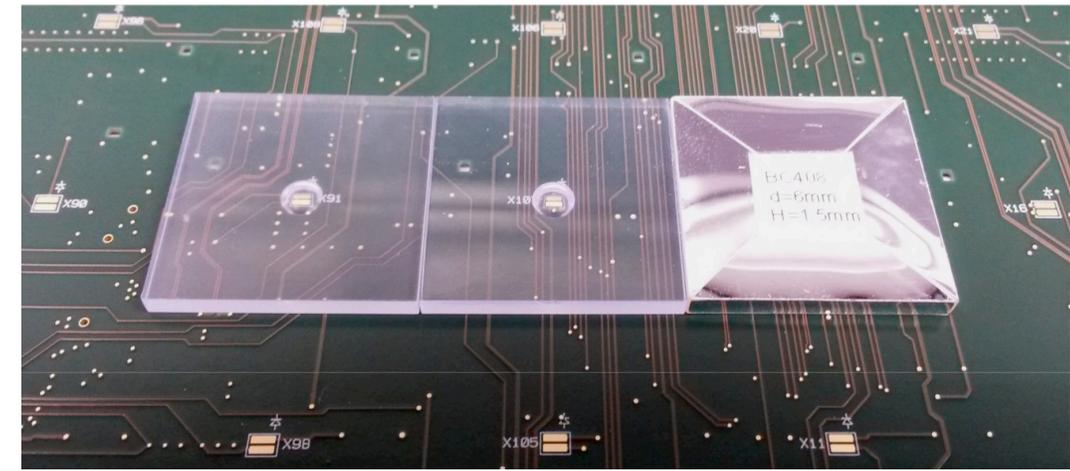
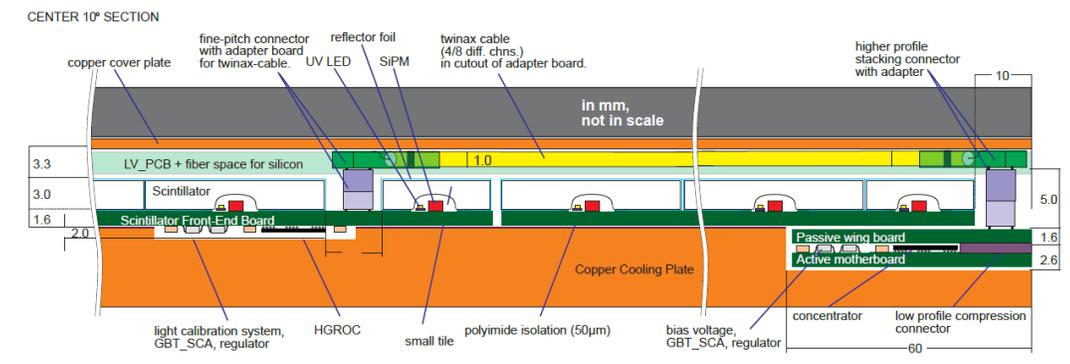
HGCAL active layers

Silicon sensors

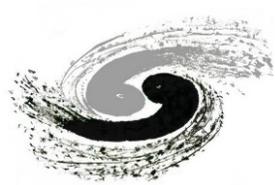


IHEP-CMS team majorly works on the silicon option, which will be focused in the rest of slides

Scintillator + SiPM

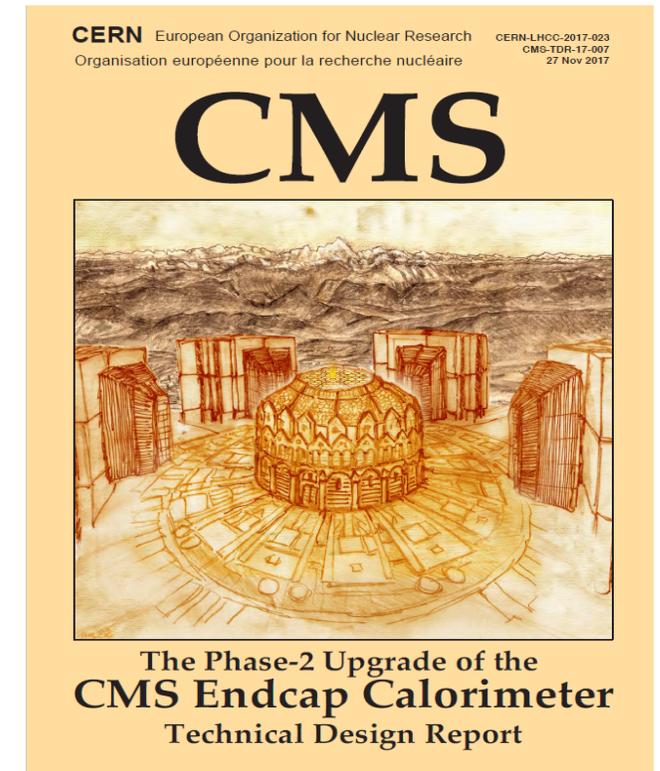


Design ("SiPM-on-Tile") for CALICE-AHCAL prototype adopted as the **baseline** for CMS-HGC scintillator part



IHEP team: CMS-HGC activities

- Testbeam campaigns of HGC silicon modules
 - IHEP joined each TB since 2016
 - IHEP contributions to HGC TDR (CMS-TDR-019)
 - Module performance
 - Paper on beam tests of silicon modules
 - Published on [JINST](#) in Oct 2018
 - Highlights of 2018 TB shown later
- Module Assembly Center (MAC) at IHEP
 - Under construction
 - Probably responsible to assemble ~20% of HGICAL silicon modules
 - Key issue: quality assurance/control (ongoing efforts)

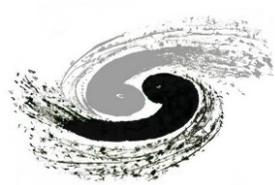


Jinst

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First beam tests of prototype silicon modules for the CMS High Granularity Endcap Calorimeter



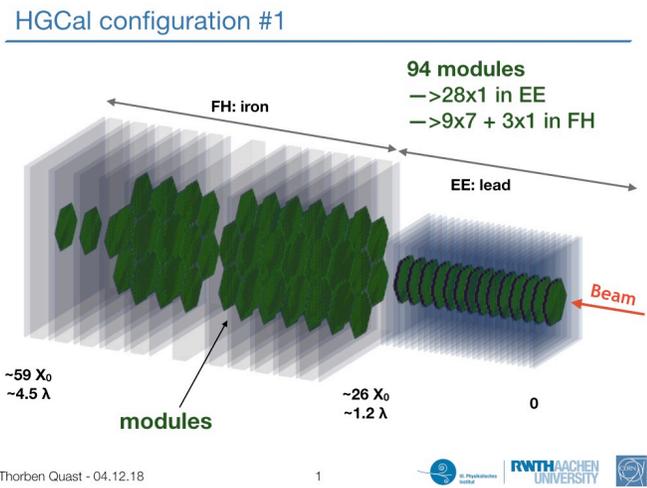
Test beam campaigns in 2018

- DESY: electron beam
 - Studies of module performance and EM showers
- CERN: SPS-H2
 - June: a full EM section of HGCal (28 layers)
 - October: a full slice of HGCal
 - 28-layer CE-E, 12-layer CE-H + 39-layer SiPM-on-Tile

DESY TB21 (2018 March)

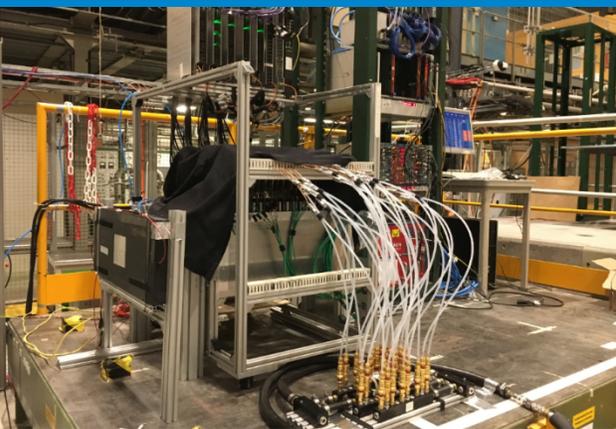


Huaqiao Zhang participated



One of various configurations tested in CERN TB in October (Plot from T. Quast)

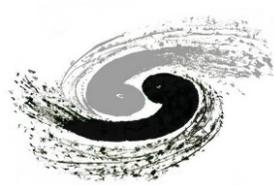
CERN SPS-H2 (2018 June)



CERN SPS-H2 (2018)



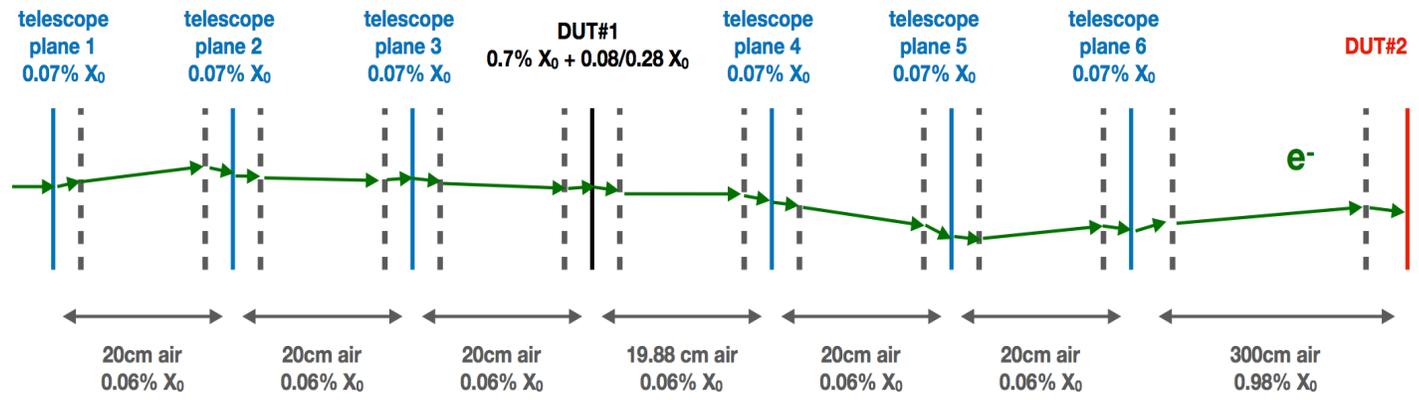
Hongbo Liao and Huaqiao Zhang participated



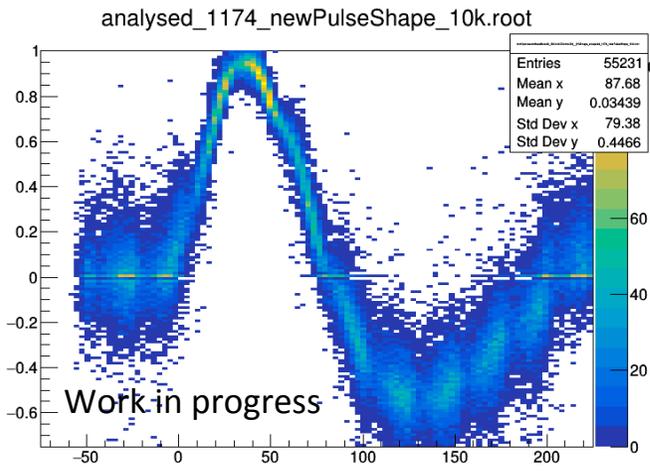
DESY beam test: highlights



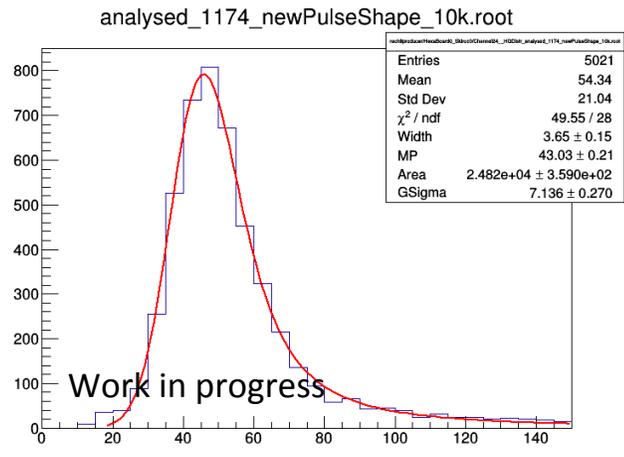
DESY TB21 (2018 March)



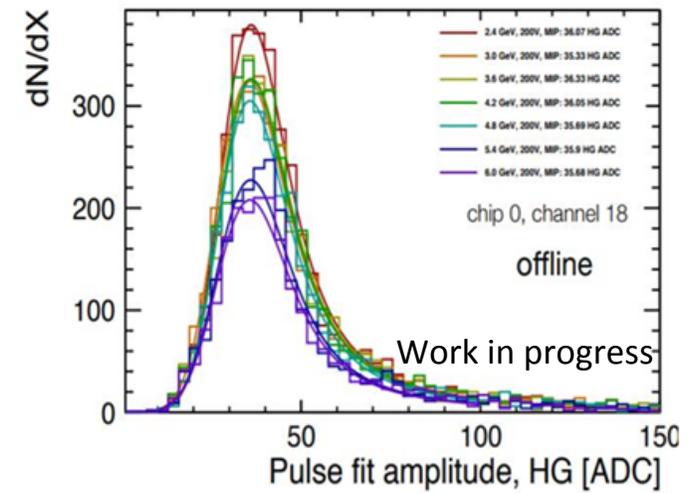
not to scale ;-)



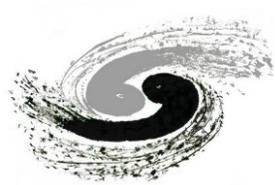
MIP signal pulse



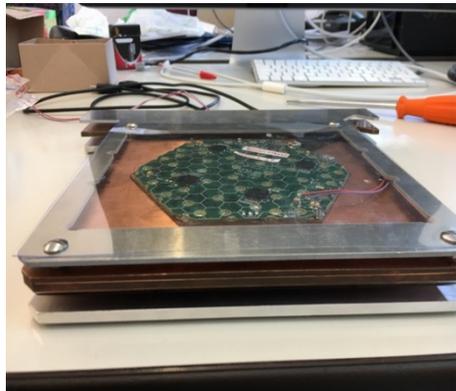
MIP signal spectra



MIP signals with e^- at different energies



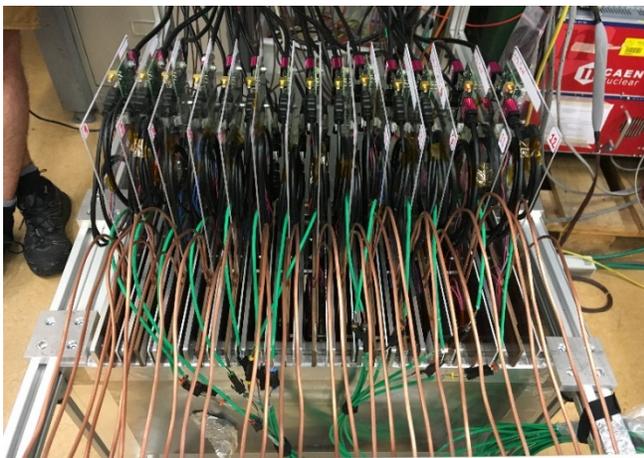
CERN June beam test: highlights



Double-sided cassette

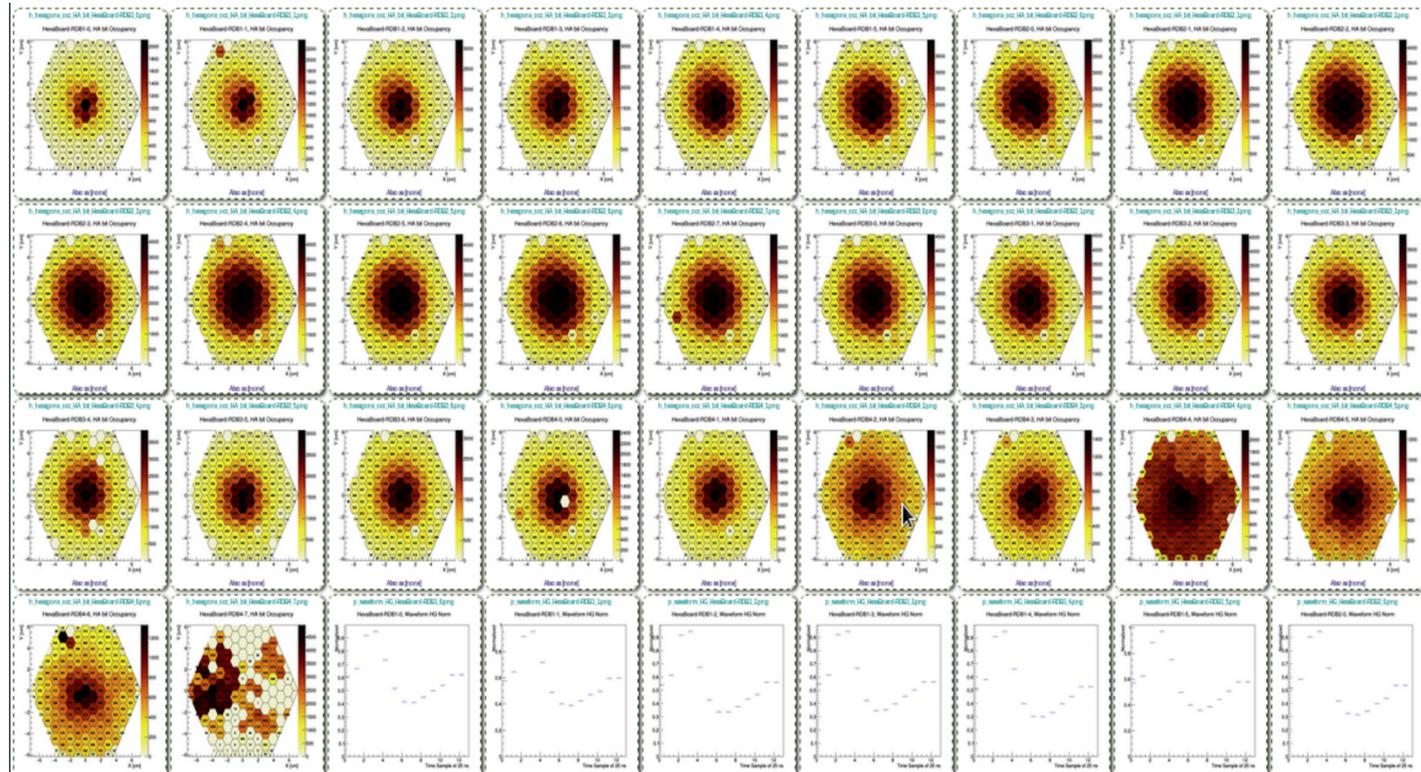


Water Cooling

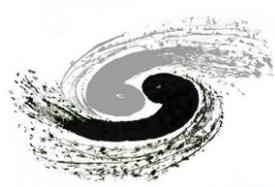


28 modules in 14 cassettes

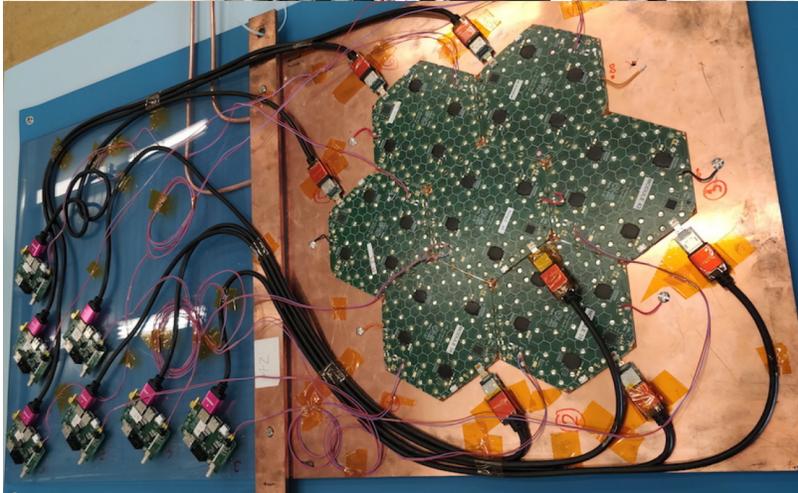
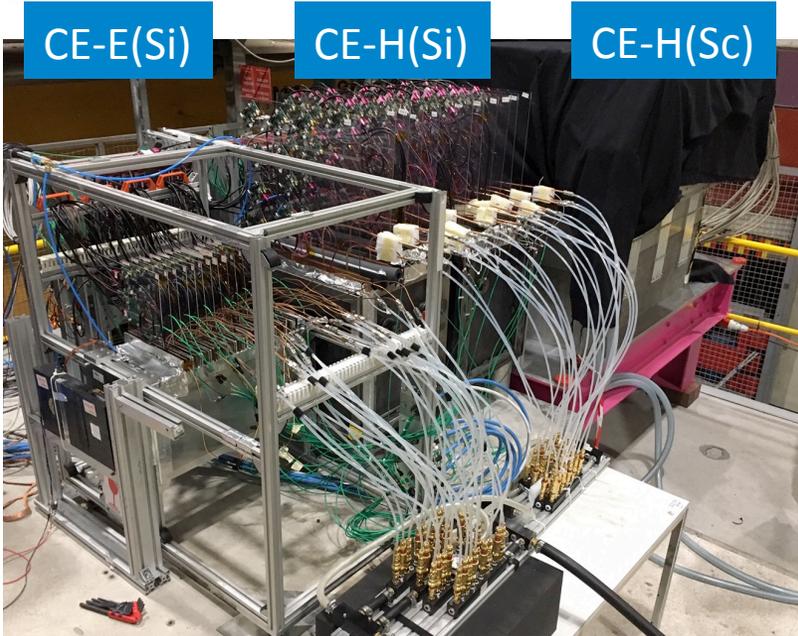
Shower shape: transverse development in each (longitudinal) layer



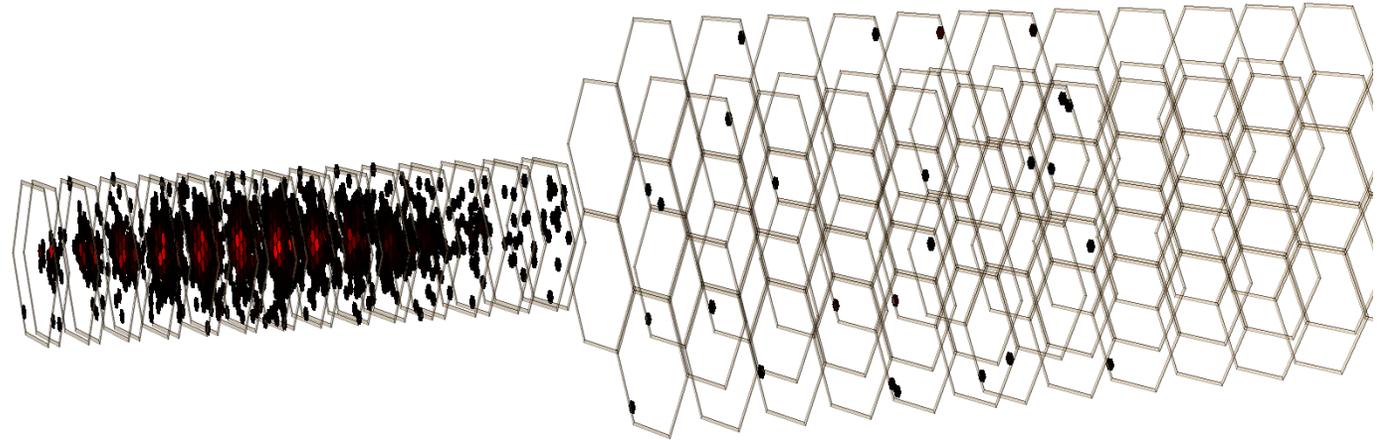
- 100GeV electrons: occupancy plots for all 28 layers
 - High noise level in the last 3 layers
- The last module (a bare hexaboard): timing reference



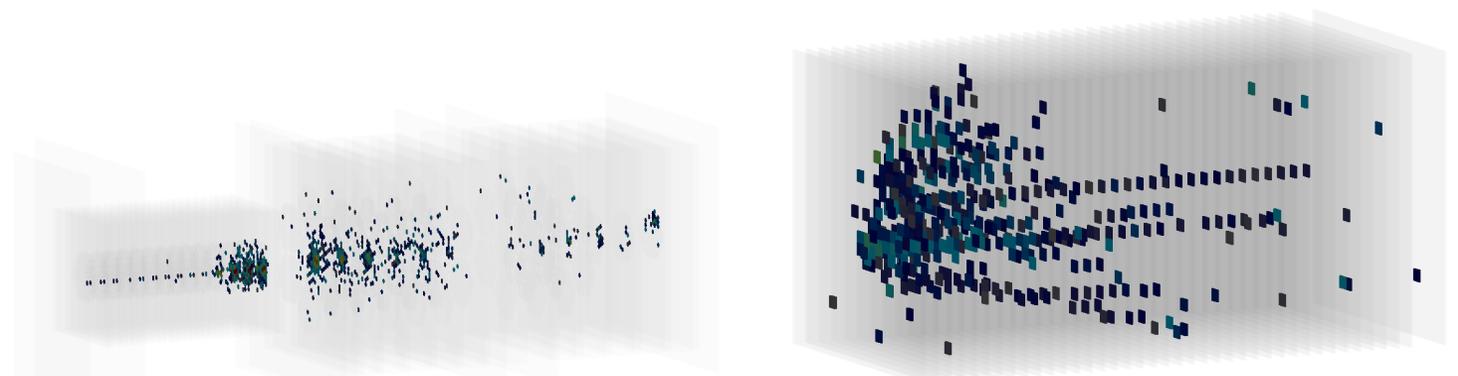
CERN October beam test: first impressions



Event display: 300 GeV EM shower

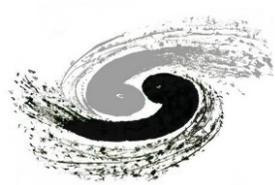


Event display: 300 GeV hadronic shower



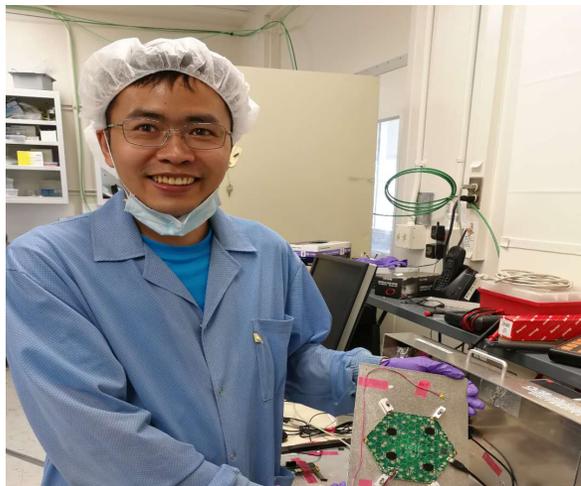
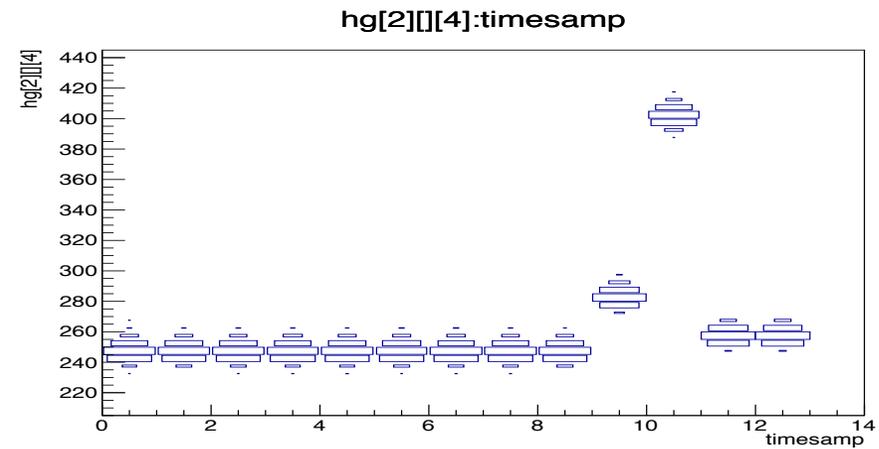
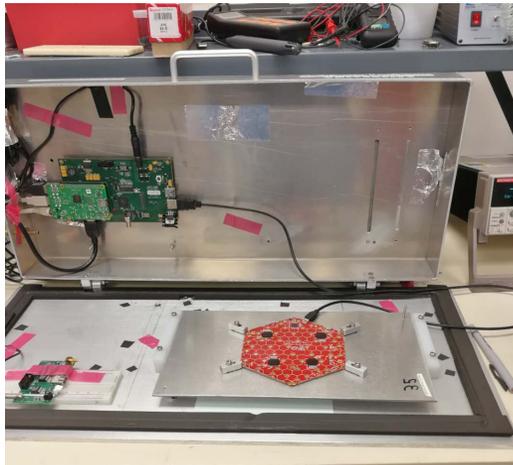
A full slice of HGCAL (studies ongoing)

Plots from A. Steen

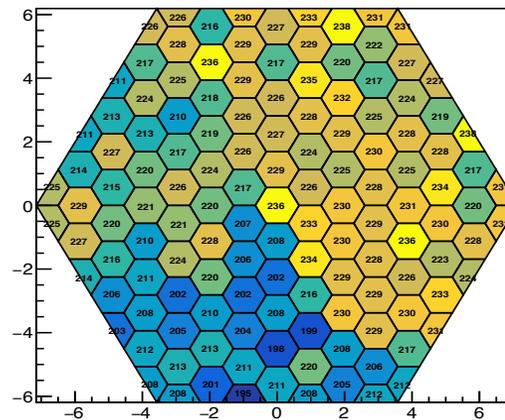


Participation in HGC PCB testing

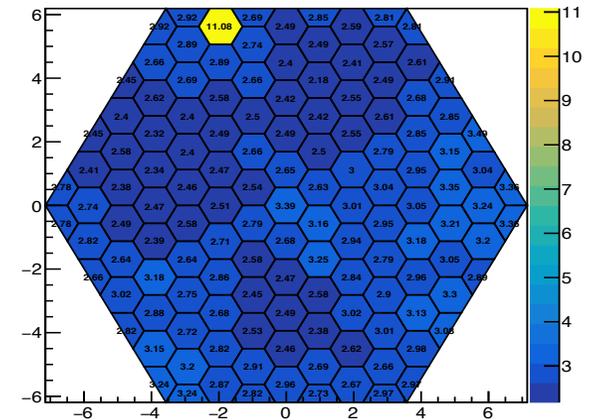
- PCB-V3 testing at UCSB: important step before beam tests

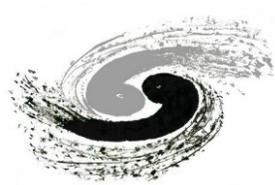


Mean (ADC) for hg sca 1



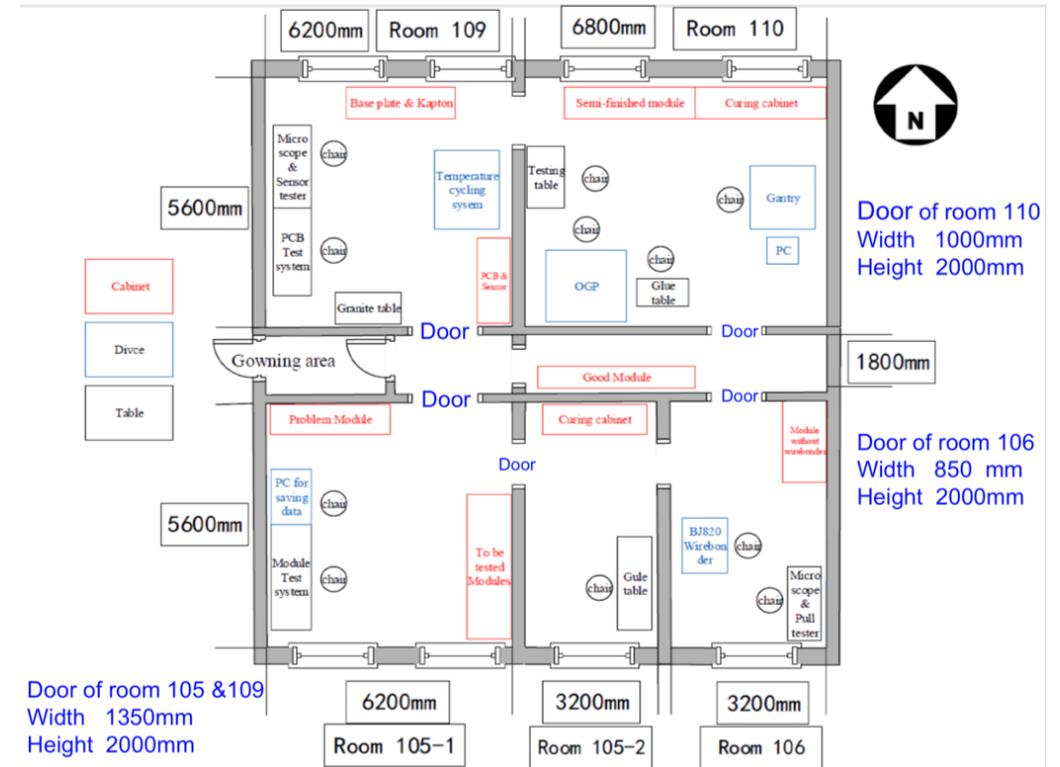
Ped RMS (ADC) for hg sca 1

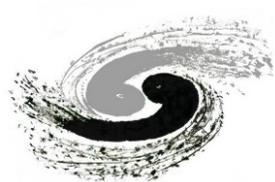




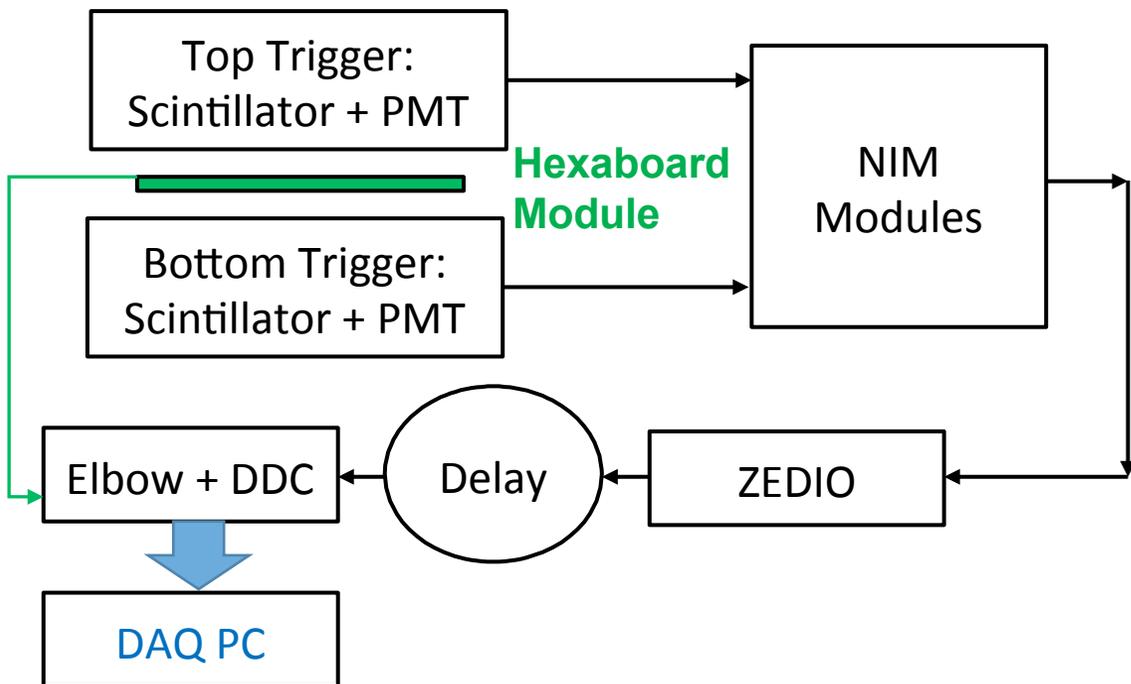
IHEP-MAC status

- HGC Module Assembly Centers
 - UCSB: the pilot MAC
 - 5 MACs: Beijing-IHEP, India (BARC), Taiwan (NCU-NTU), US (CMU, TTU)
- IHEP-MAC: in preparation phase
 - Clean room: under construction
 - Instrumentation: being investigated/ordered
 - Bonder, gantry, optical gauging
 - Custom-designed tooling
 - Probe stations, glue dispenser, ...
 - HGC lab: test stand development





Cosmic-ray test stand at IHEP

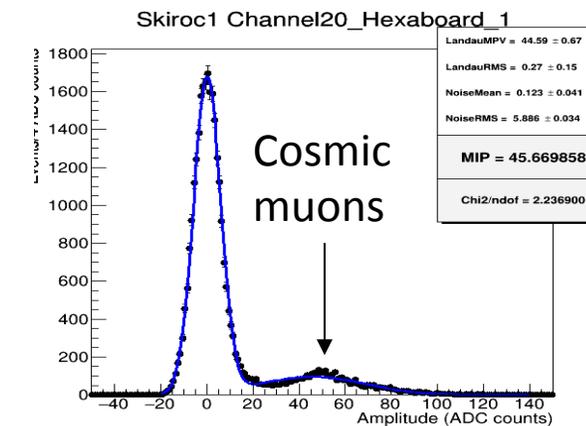
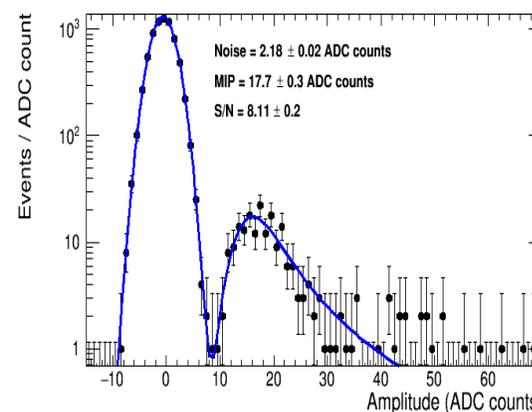
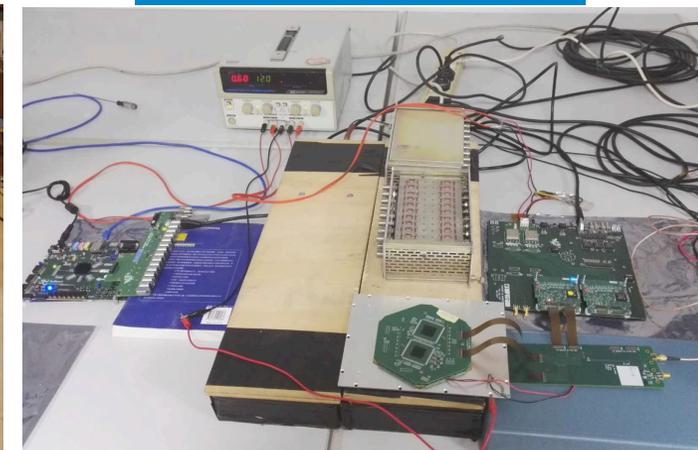


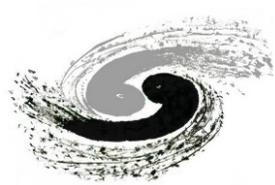
- Successfully built cosmic test stand
 - At CERN first and later at IHEP
- Tested modules with cosmic muons
- Plan to move to IHEP beam area
 - Studies with high-intensity GeV electrons

Cosmic setup at CERN



Cosmic setup at IHEP





Summary

- CMS-HGC activities
 - Module assembly, PCB testing and beam test campaigns
- Module assembly center at IHEP: under development
- Man power ramping up
 - Physicists (5+): H. Liao, H. Zhang, **Yong Liu**, F. Wang (postdoc), B. Li (PhD) + more
 - Engineers (8): X. Cao, Y. Gu, X. Li, X. Liu, B. Meng, L. Sun, C. Zhang, W. Zhang
- Future plans
 - Module assembly: training and exercise
 - Module beam test at IHEP-TBF (E2 line)
 - Linearity measurements with primary electron beam (up to 2.5 GeV)
 - Silicon sensors R&D: low leakage current, radiation tolerance, ...

Thank you!