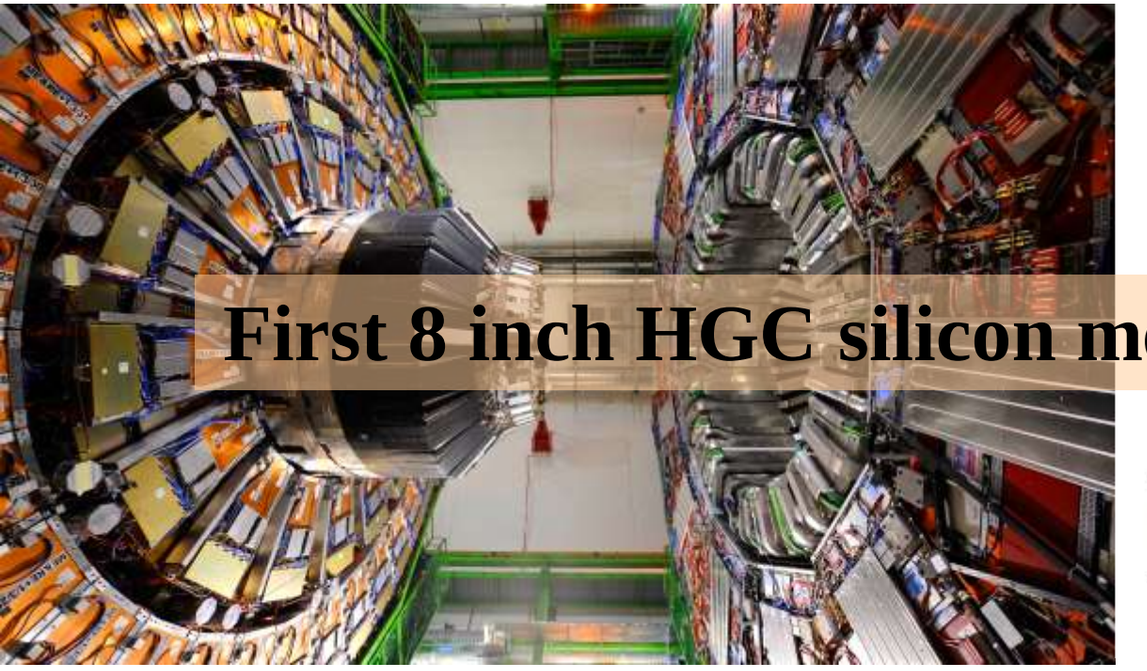
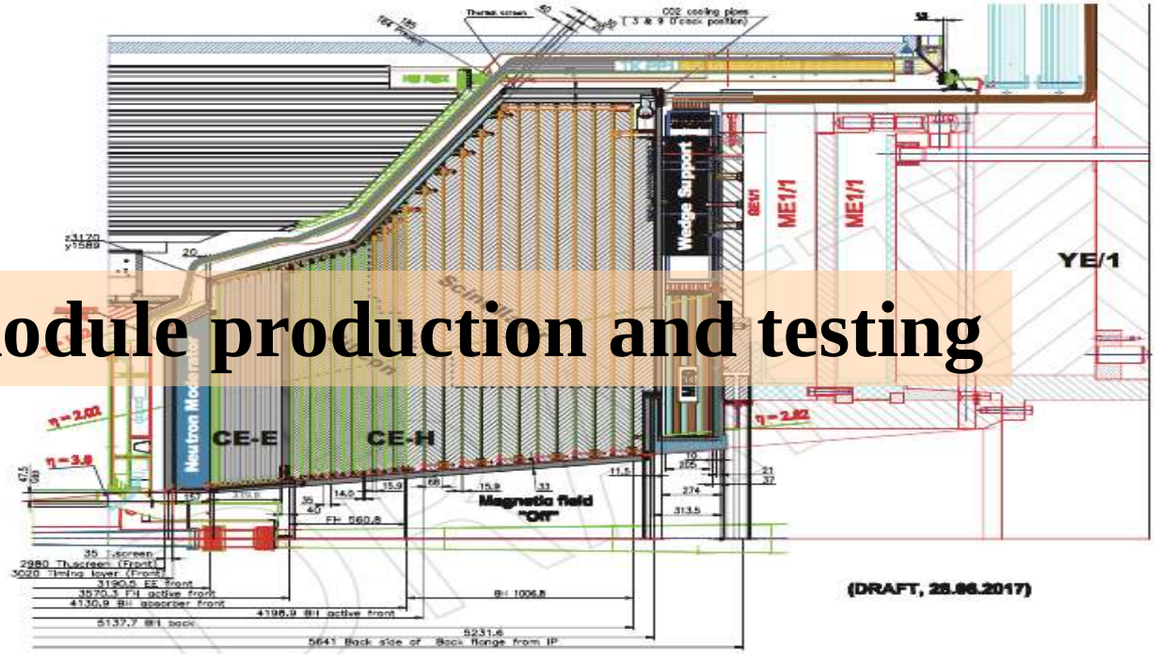
中國科學院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences
Beijing





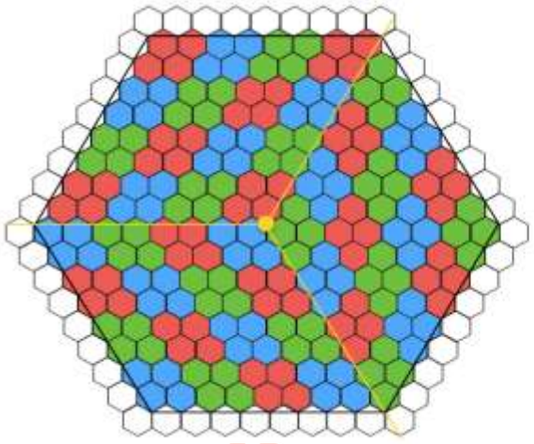
First 8 inch HGC silicon module production and testing

Feng Wang

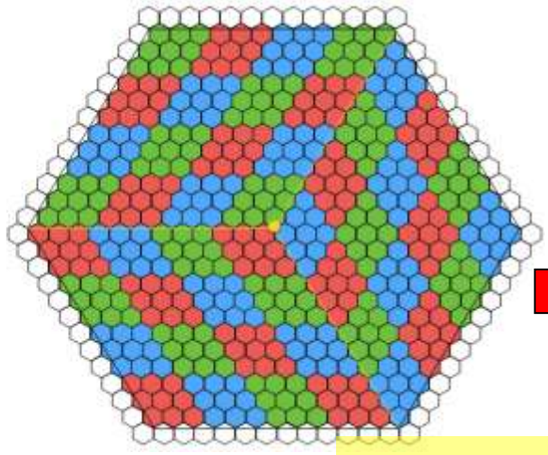
On behalf of the HGCal IHEP group

27/11/2021

Structure of CMS endcap calorimeter

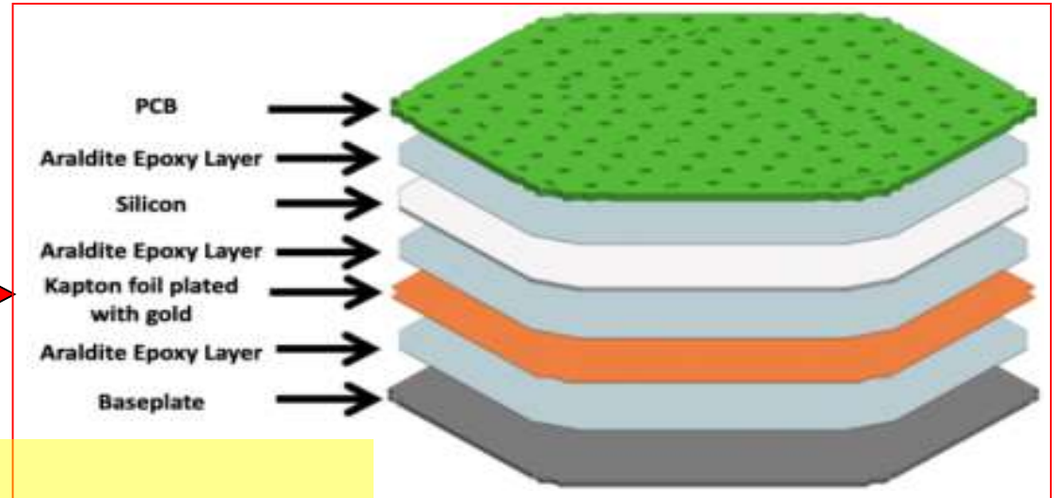


LD



HD

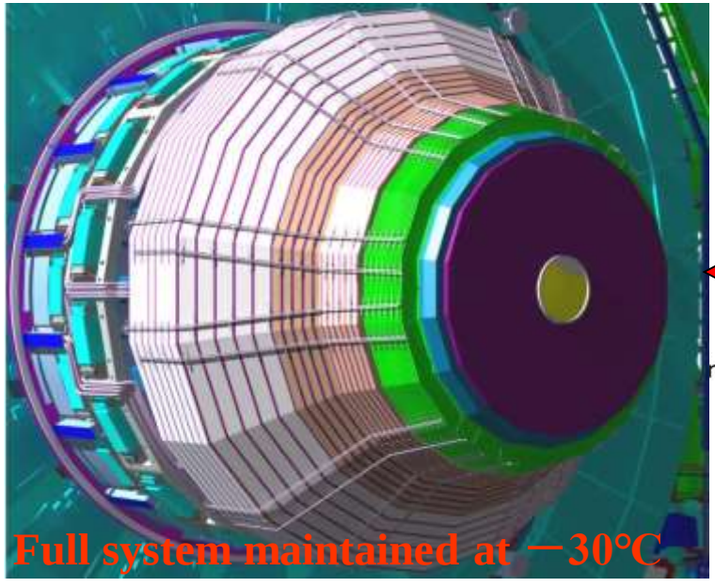
8 inch sensor



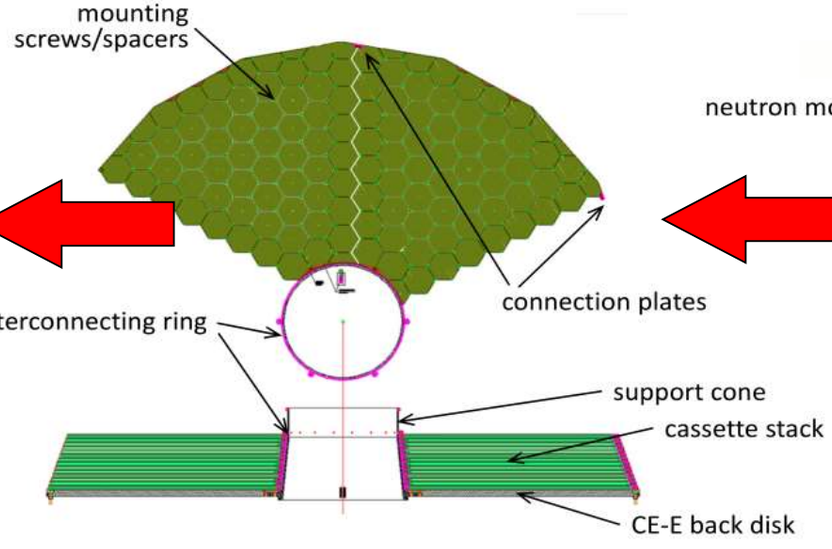
HGCal Module

5D calorimeter :

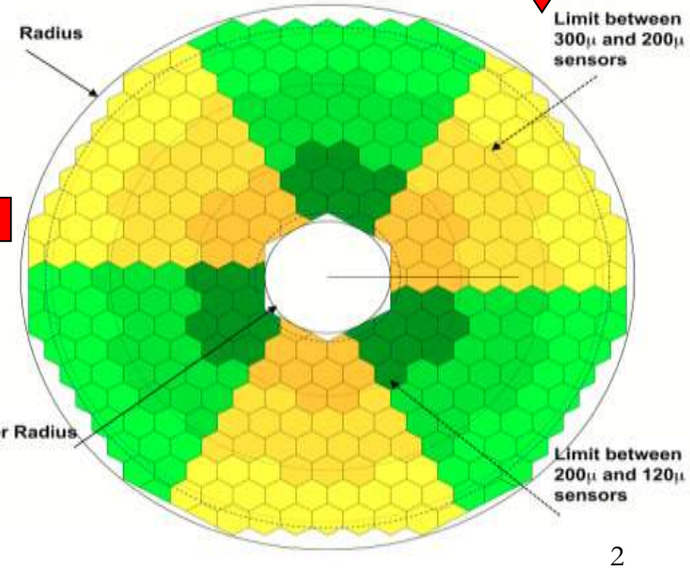
- ~640m^2 of silicon sensors
- ~370m^2 of scintillators
- 6M Si channels, 0.5 or 1.1 cm^2 cell size
- ~31000 Si modules



Endcap calorimeter



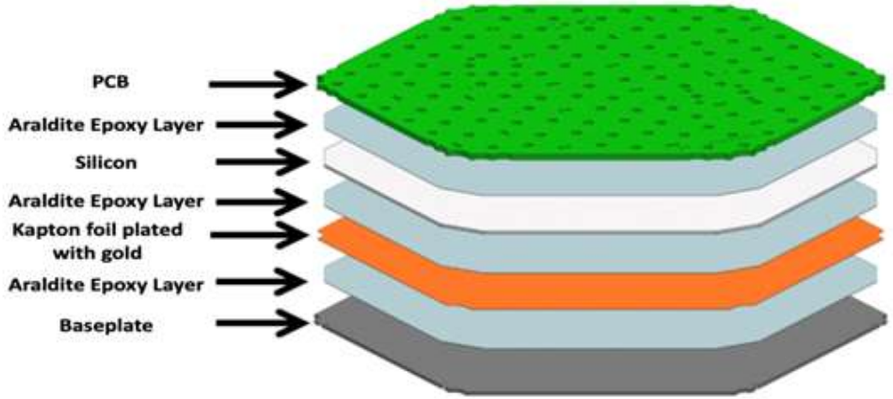
Stacking



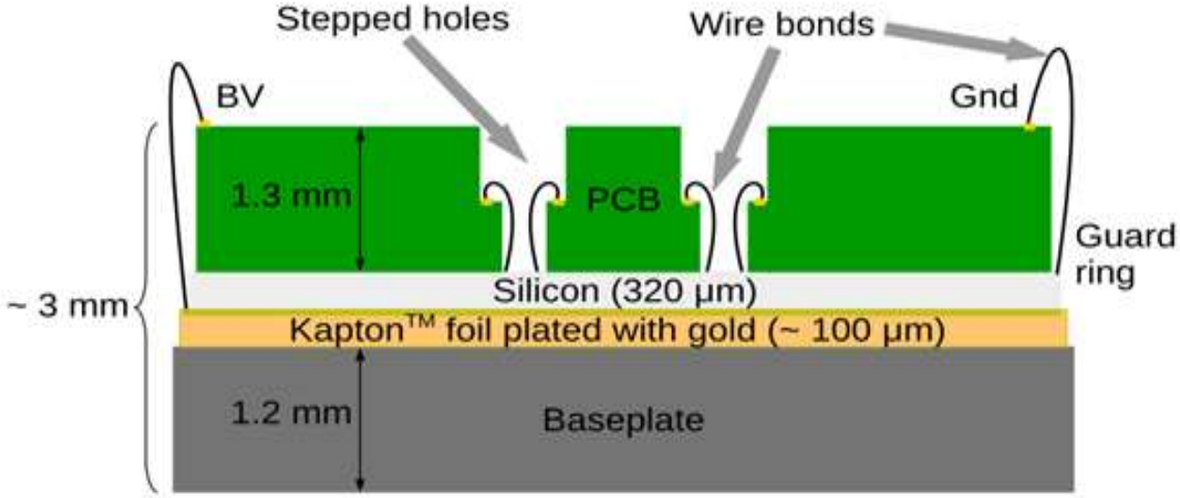
Tiling

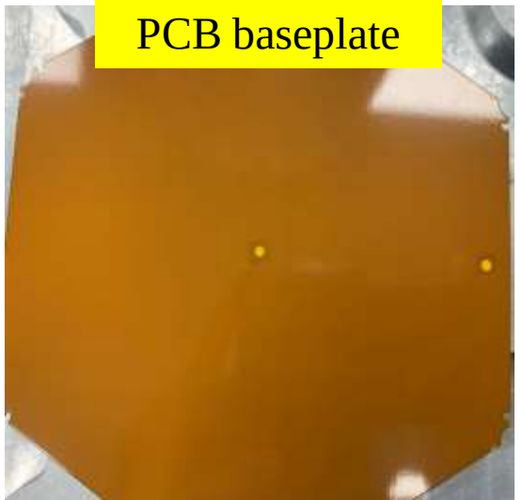
CMS HGCal module

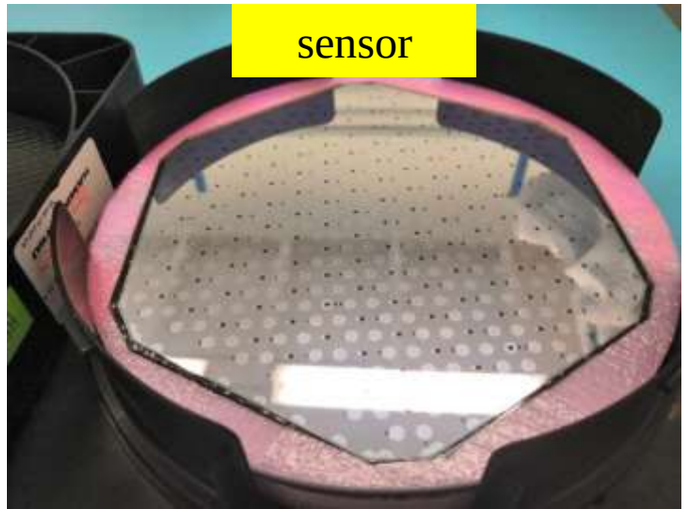
- Absorber: PCB (FR4) baseplate for CE-H & CuW baseplate for CE-E
- Sensor: 8 inch with120μm, 200μm and 300μm depletion depth for different radiation level
- PCB: Hexaboard with front-end electronics ASIC (HGCROC)
- Assemble module by glue in each layer

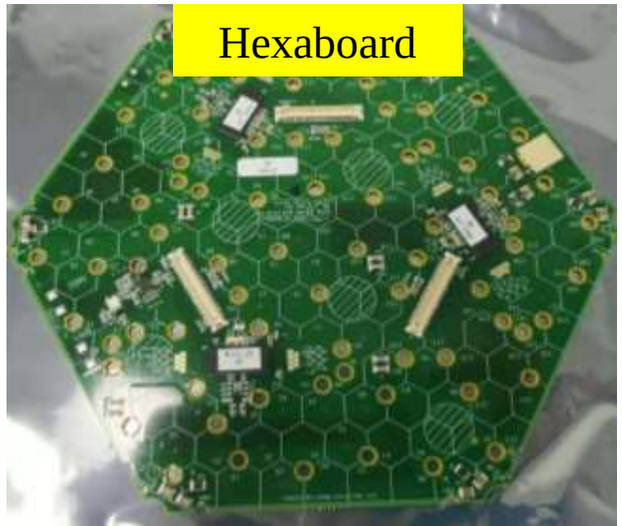


- Wire bonding for signal read out, guard ring and BV
- Protect wire by encapsulation









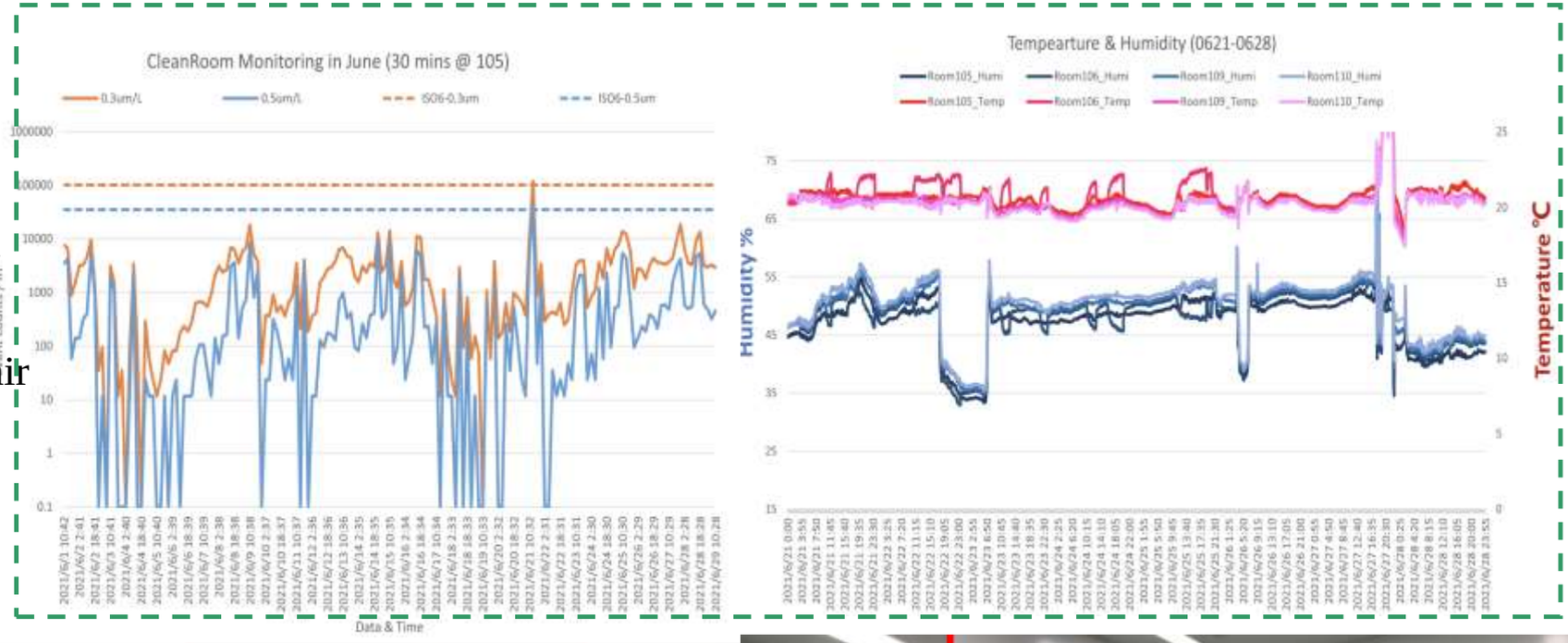
Module assembly requirements

- Module assembly lab
  - Clean room with temperature：21±1°C and humidity：45% ±10%
  - Key equipment: Gantry, bonder, OGP, pull tester, mini gantry, teststand, microscope, etc.
- Selection of components
  - Flatness of baseplate and sensor: less than ±50μm
  - No fatal scratches found on the sensor
  - Acceptable noise level for front-end board （Hexaboard）
- Key indicators for QC in the module assembly process
  - Glue coverage area greater than 70% for heat dissipation
  - Thickness of epoxy glue layer in the assembly procedure: 100μm±25μm
  - Edge-to-edge alignment less than: ±30μm
  - Pulling force of a single bonding wire >8g
  - Single module (LD) with 192 channels requires more than 600 wires
  - All bonding wires are encapsulated
- Module testing
  - Good noise and IV performance before and after assembly into modules

We have met the above requirements at IHEP MAC

IHEP HGCal lab

- 140m^2 dedicated clean room （Class 1000）at the ready：
  - Continuous operation for one year
  - Temperature and humidity have good performance
  - Compressed/vacuum/dry air pipe installed
  - Key equipment is ready
  - Training over



Dispense

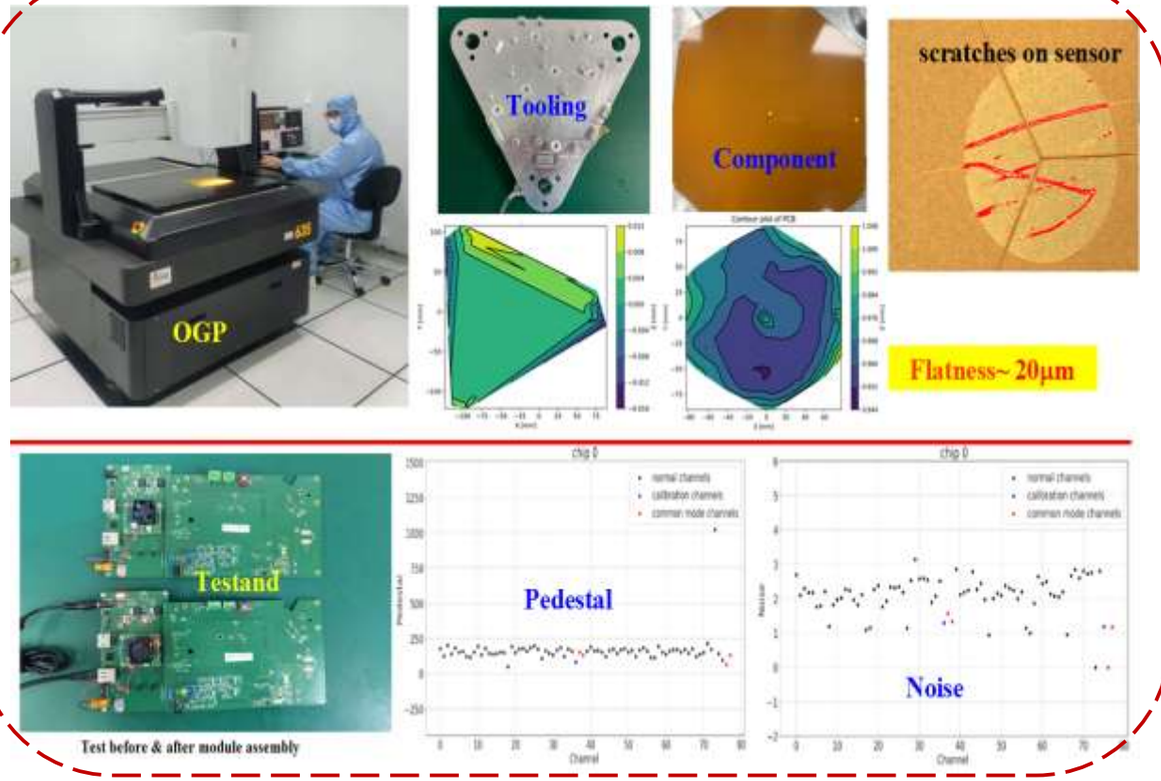
Wire bonding

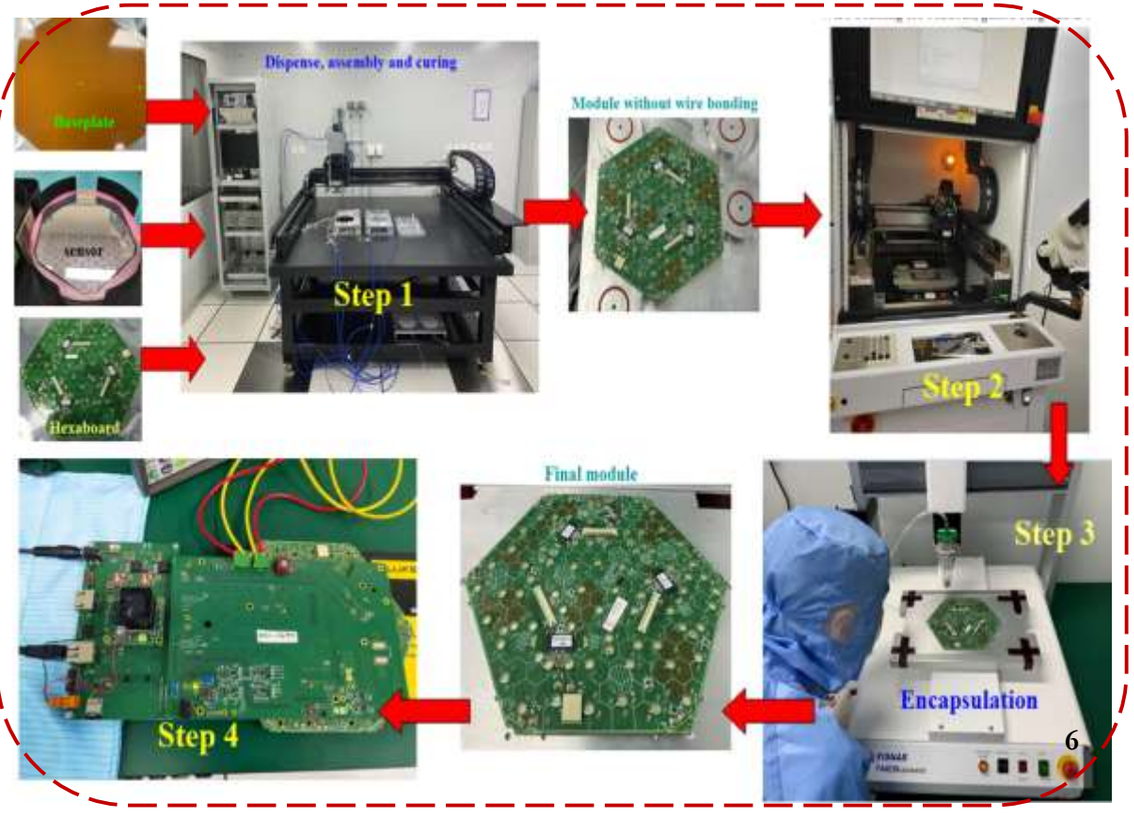
Pull test & encapsulation

Module test

HGCal module automatic assembly procedure

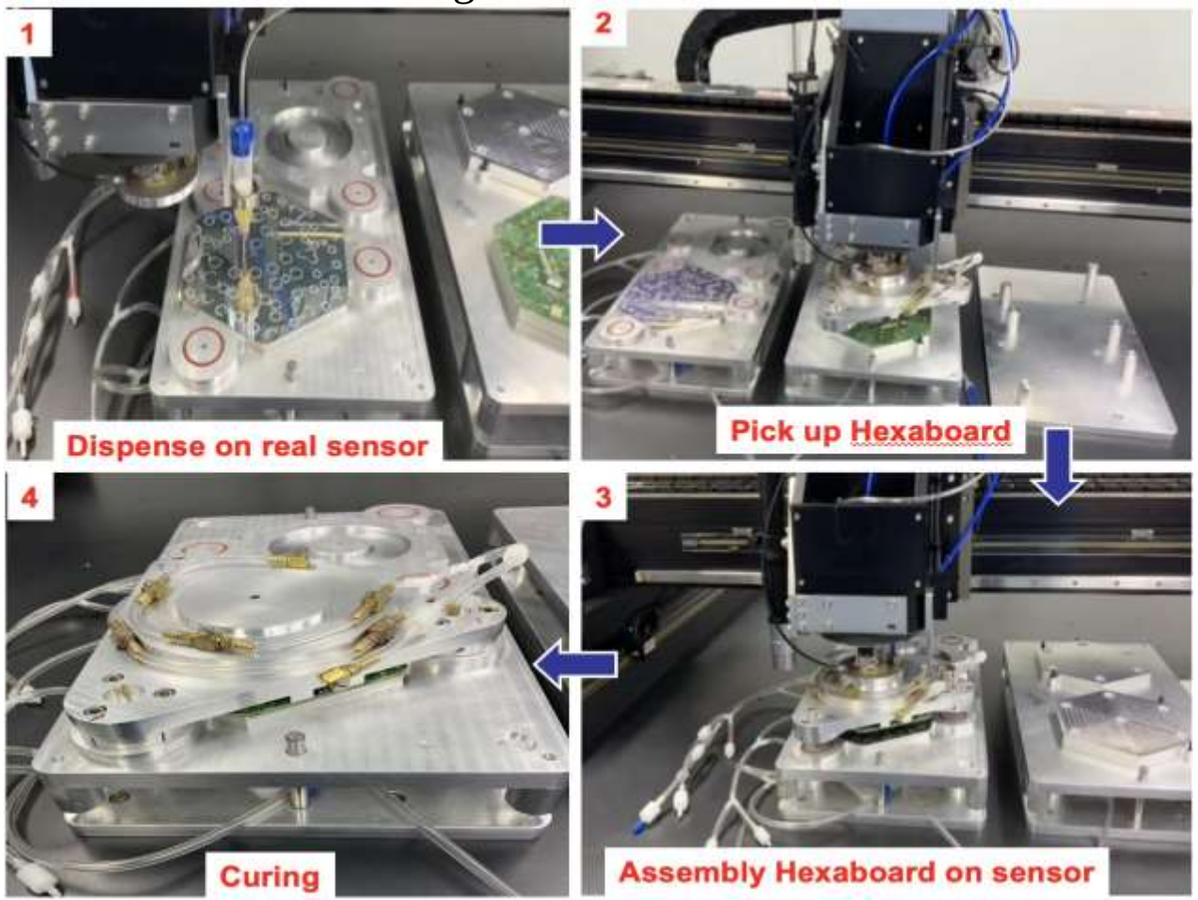
- Check components before assembling
  - Thickness, size, etc. measurement for baseplate by OGP
  - Scratch inspection on sensor by OGP
  - Pedestal, noise, etc. testing for hexaboard by testand
- Single module automatic assembly
  - Step 1: the baseplate, sensor and hexaboard assembly on the gantry
  - Step 2: wire bonding for read-out, guard ring and BV are operated on the bonder
  - Step 3: test module with wire bonding and without
  - Step 4: encapsulation for protecting bonding wire is carried out on the mini gantry
  - Step 5: teststand is for the full tests of the noise and IV performance of module (after assembly)



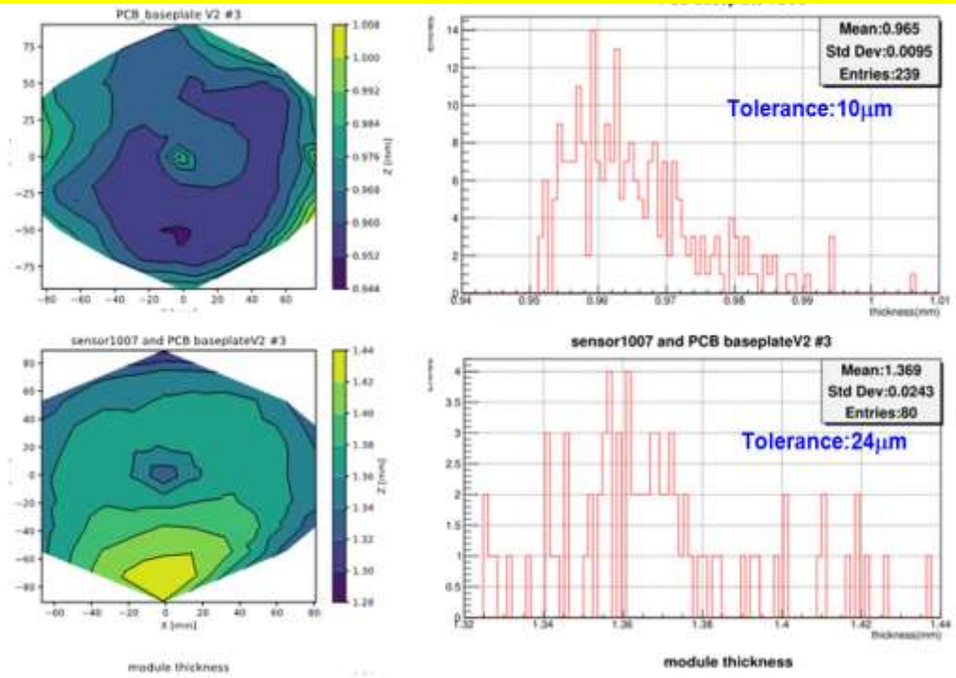


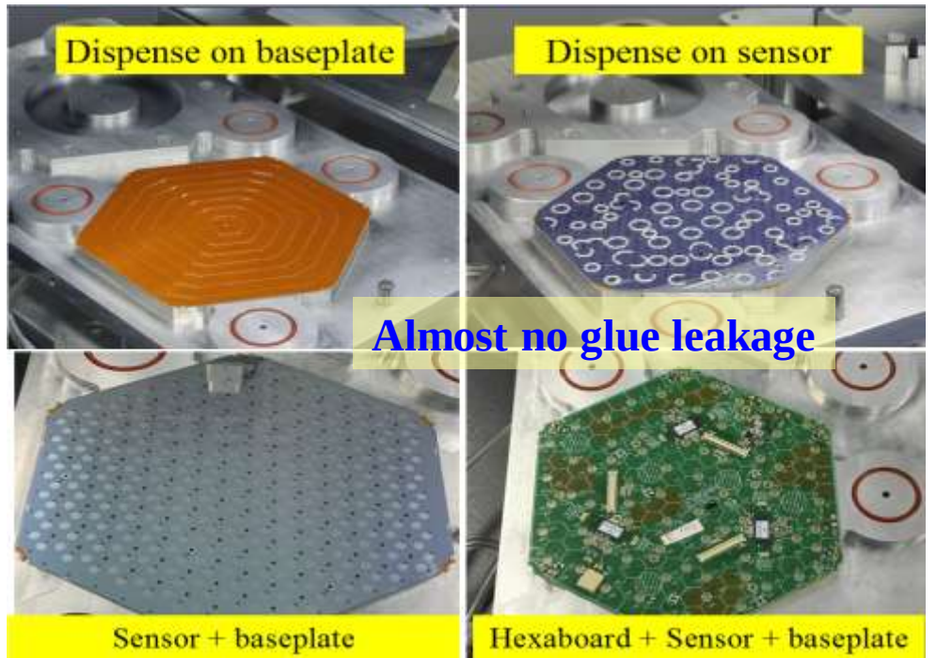
High precision automatic assembly

- Automated assembly on the gantry
  - Calibrate the components position by CCD
  - Dispense on the component
  - Pick up the specific tooling by vacuum
  - Pick and place sensor (hexaboard) on baseplate (sensor)
  - Curing for 24 hours
- Performance
  - Glue thickness meet the requirement
  - Glue cover area lager than 70%



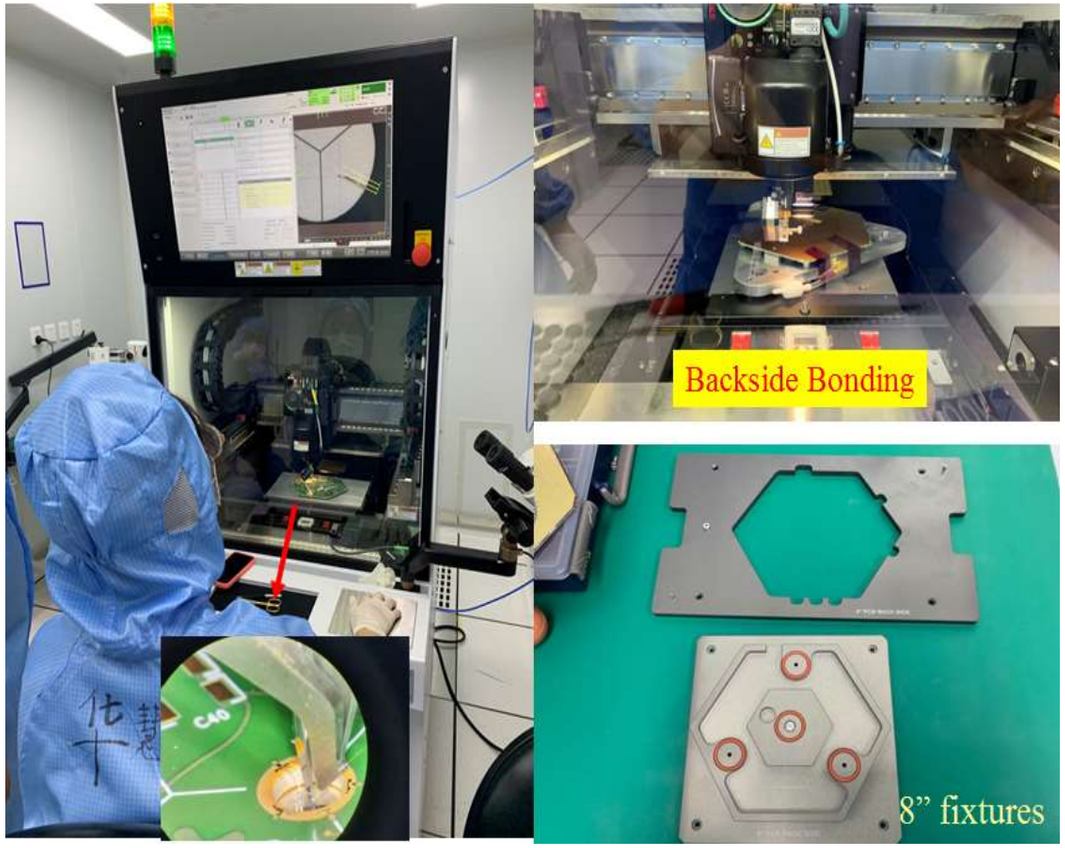
Glue thickness: 1.369－0.300 － 0.965= 0.104mm

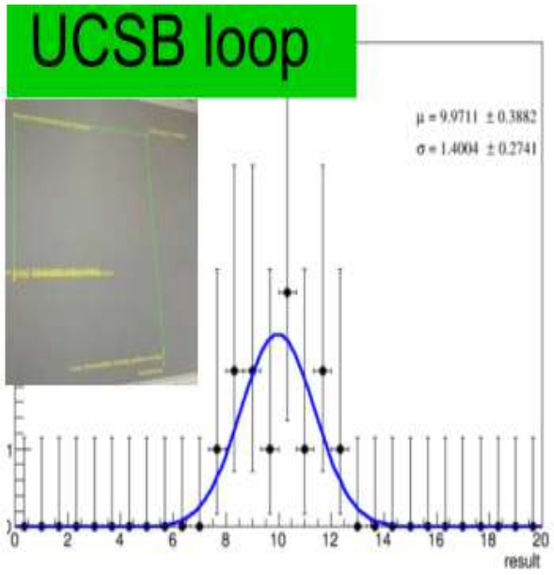




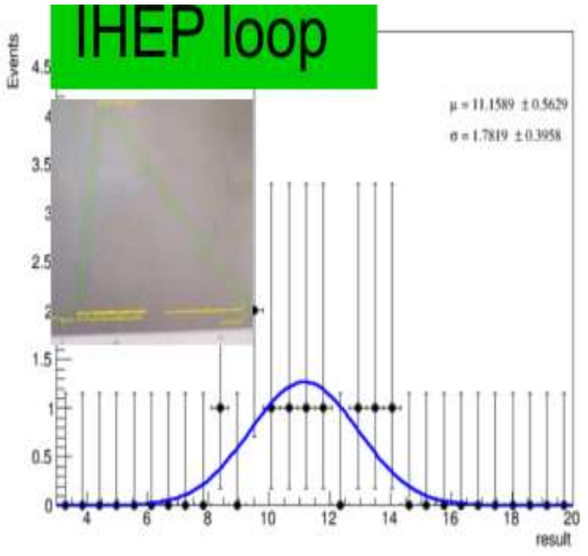
High speed automatic wire bonding

- Wire bonding
  - 4 wires (23 μm) can be bonded per second
  - Specific tooling holds module on the bonder
  - Front side bonding is for read-out and guard ring
  - Back side bonding is for bias voltage
  - 3 wires for each pixel
- Performance
  - Pulling forces of a single wire greater than 8g



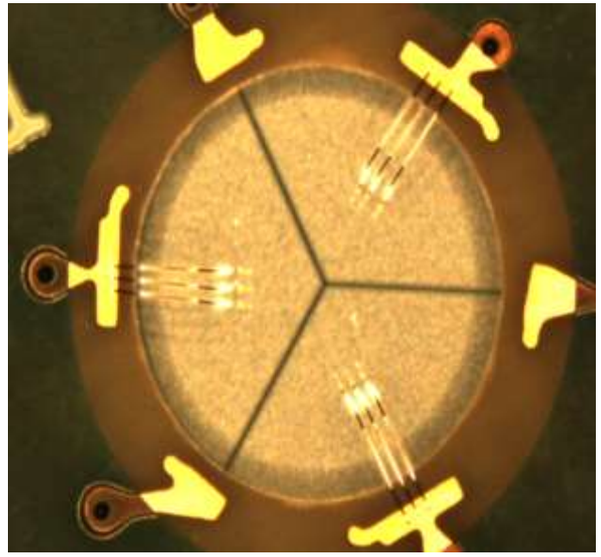


We tested 14 wires for new loop.
The mean value of the pull force is 9.97gf.
σ is 1.4.



We tested 10 wires for old loop.
The mean value of the pull force is 11.16gf.
σ is 1.8.

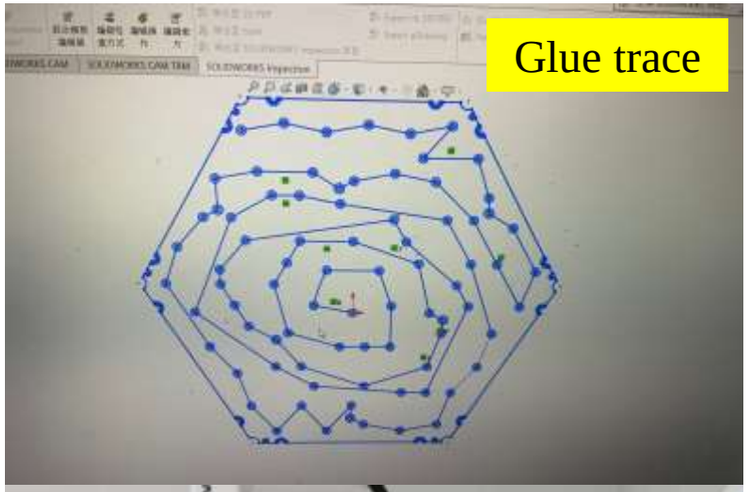
Read out bonding

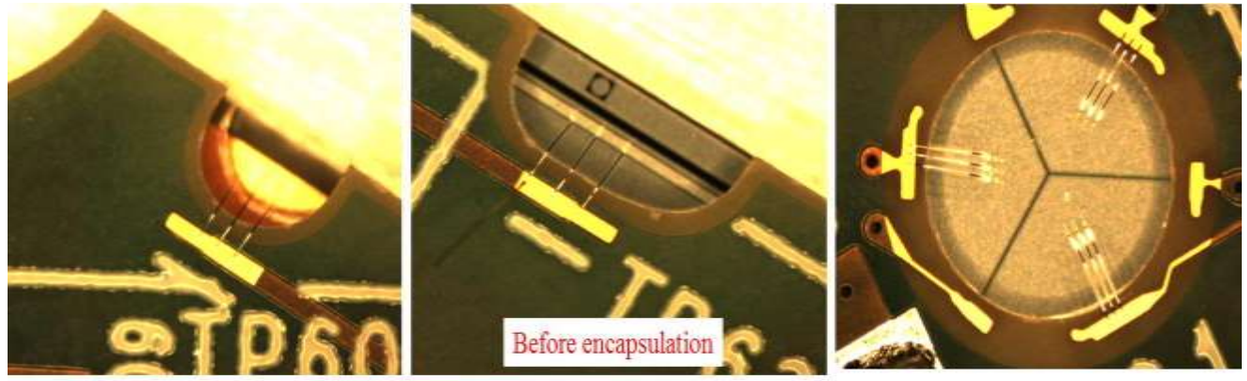


Guard ring bonding

Automatic encapsulation

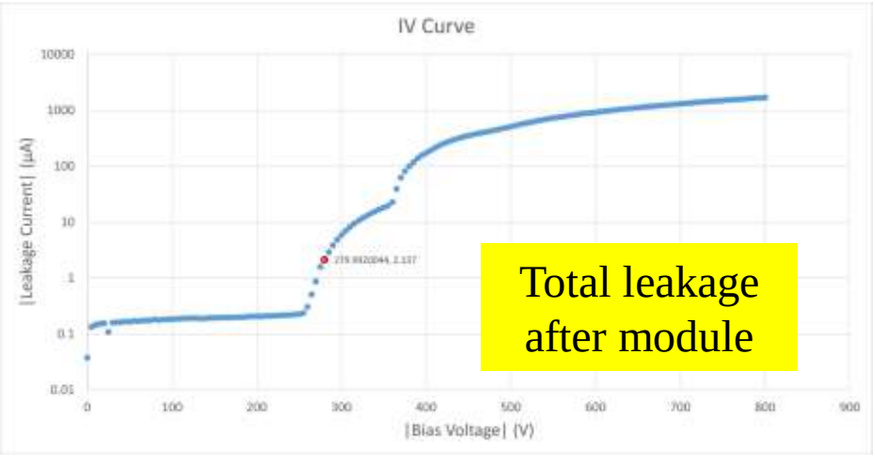
- Glue: Sylgard 186 1:10 (mass) which is a clear silicon glue with very high radiation tolerance
- Centrifuge is used to remove air bubbles
- Automatic glue dispense for encapsulation on the mini gantry

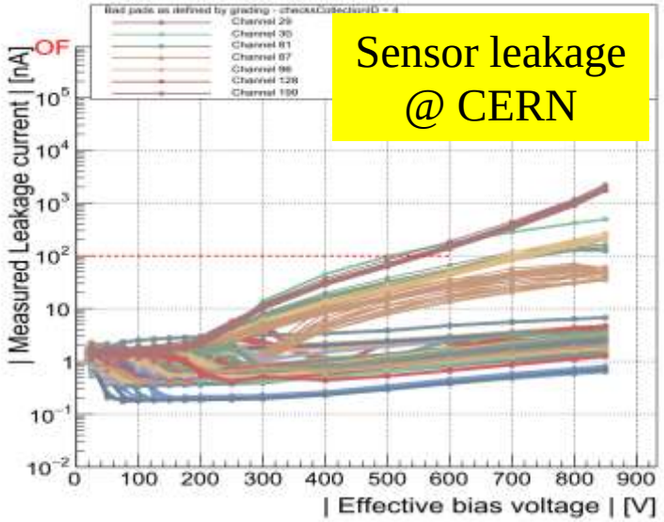


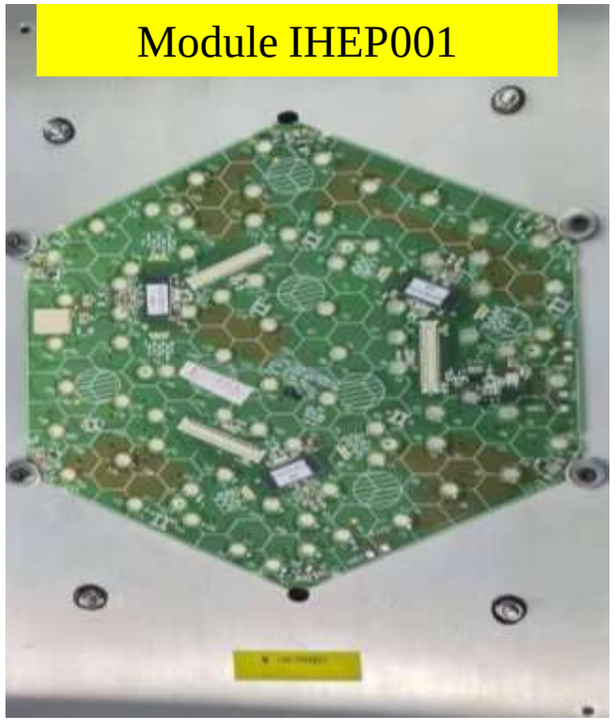


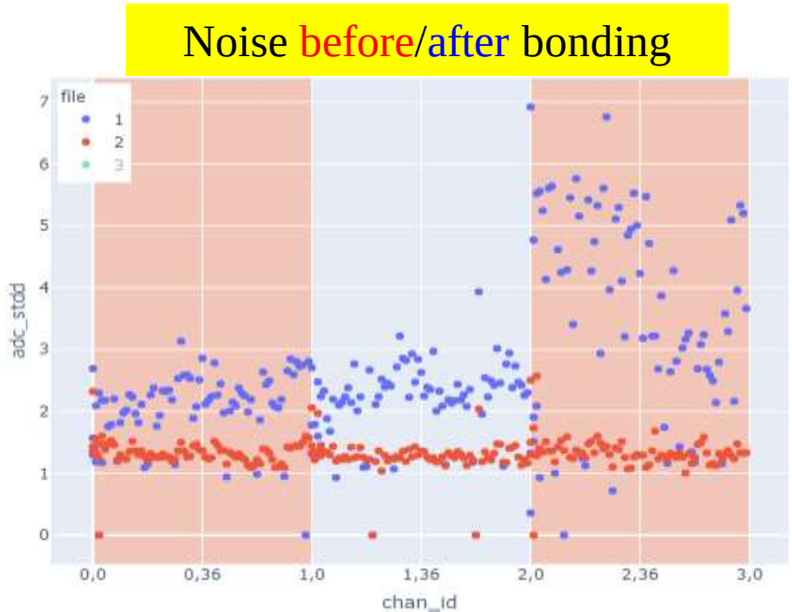
First 8 inch HGCal Module @IHEP

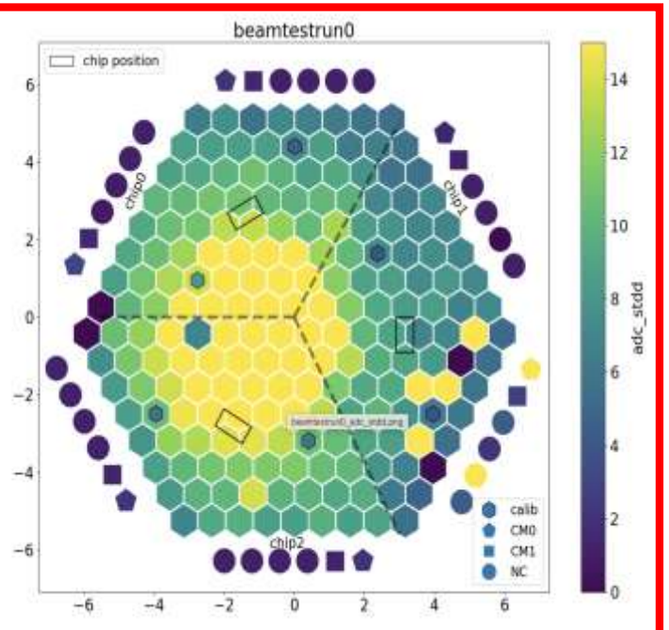
- Test leakage, Pedestal, Noise, etc.
- First test beam for 8 inch HGCal module at CERN











Summary and Plan

- **First 8 inch HGCal module assembly success at IEHP**
  - All assembly procedure has been video recorded step by step and shared with CMS HGCal group
  - The thickness control, wire pulling force and encapsulation of this module mainly meet the requirements
  - The electronics test of this module is normal, and detects the signal in the beam test at CERN
  - We have mainly mastered the key technology of the single HGCal module assembly
  - Experts from CMS HGCal group express their congratulations to IHEP

- **We have done an other 8 inch HGCal module at IHEP**
  - The performance is similar with the first one
  - We sent this module to CERN and tested the beam test on Oct. 2nd, 2021
- **Prospects**
  - Optimize the module assembly process
  - Product assembly tooling to match the mass production

QC → Pre-production → Mass production

Thanks

Thankful to close collaborations with HGCAL teams, esp. CERN, UCSB and NTU