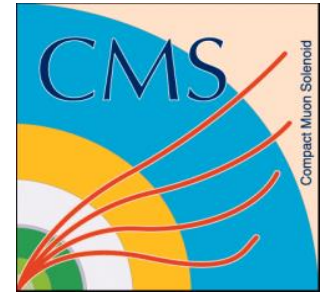




Beijing

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



Recent progress of CMS HGCal at IHEP

Feng Wang

On Behalf of CMS HGCal Working Group

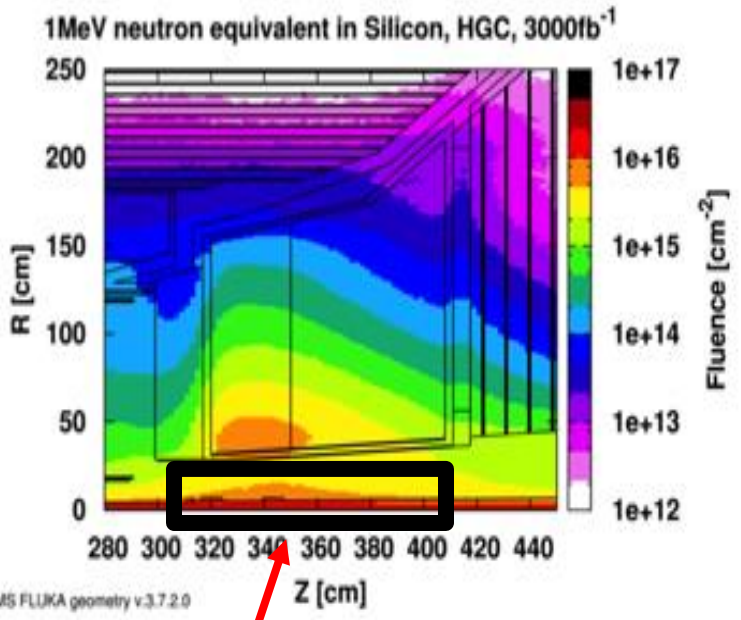
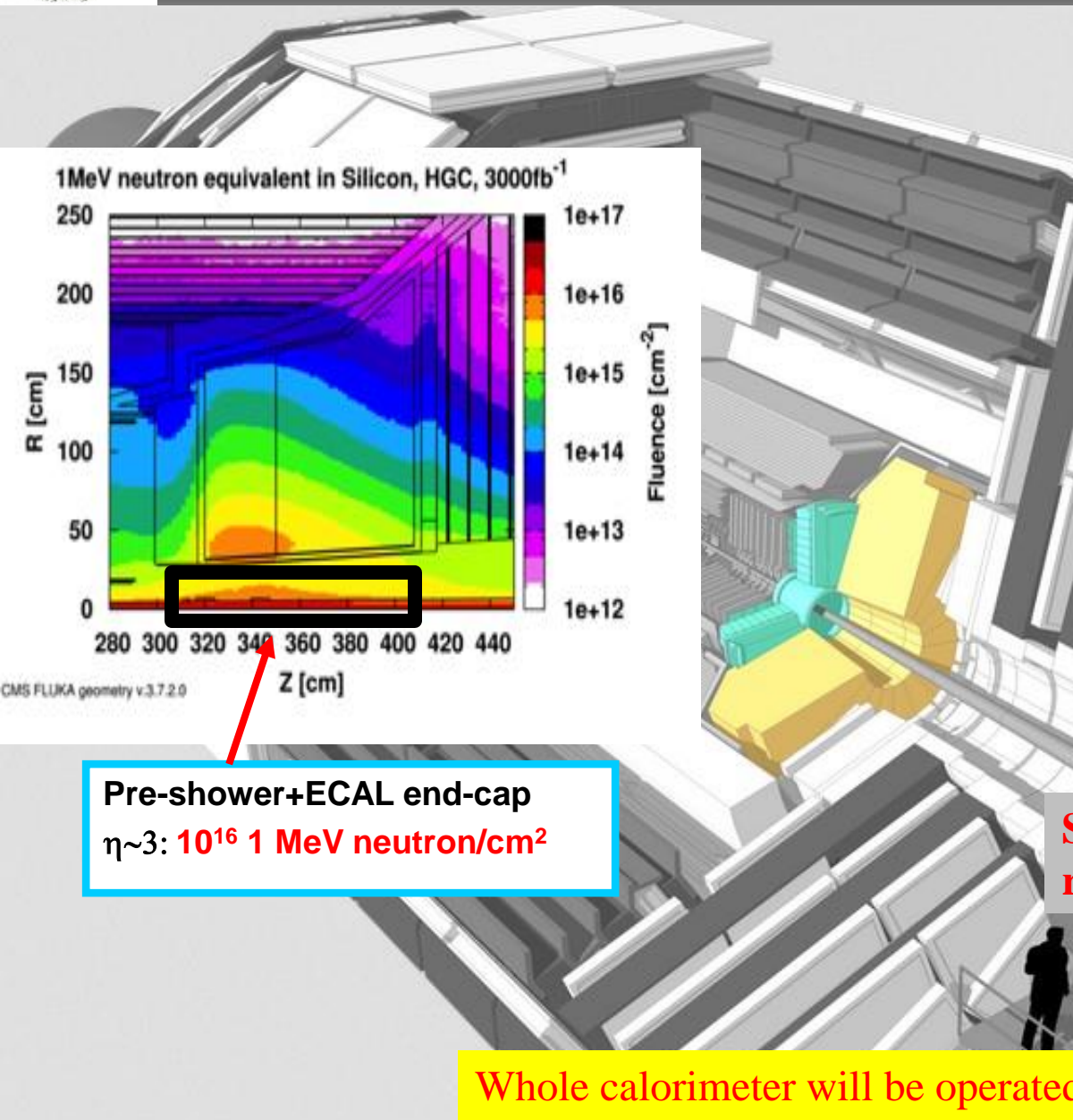
26/10/2019

Outline

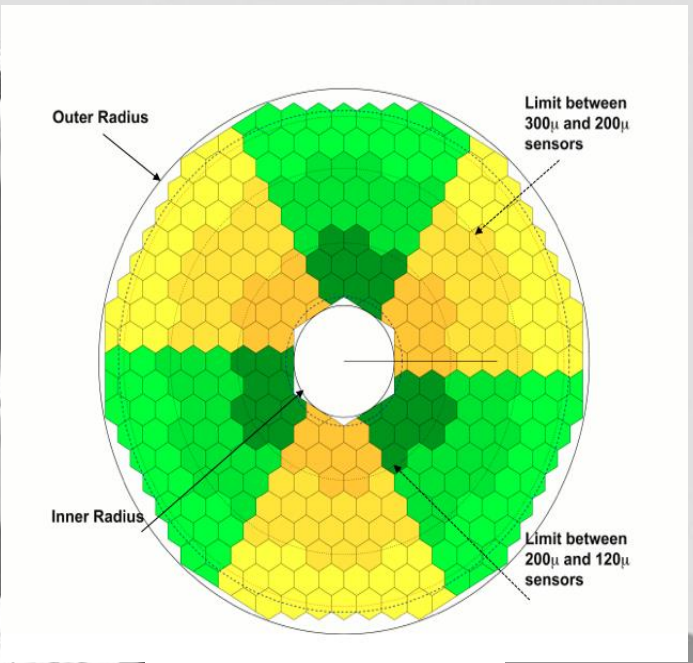
- Introduce CMS phase II HGCAL upgrade
- Status of HGCAL at IHEP
 1. Main task for IHEP in upgrade
 2. Mass production center (MAC) setup
- Next to do
 1. Aim to quality control certification



CMS High granularity calorimeter



Pre-shower+ECAL end-cap
 $\eta \sim 3$: 10^{16} 1 MeV neutron/cm²



CE-E 9th layer

Sensor thickness optimized vs radiation hardness

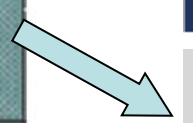
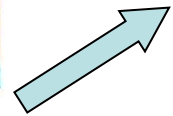
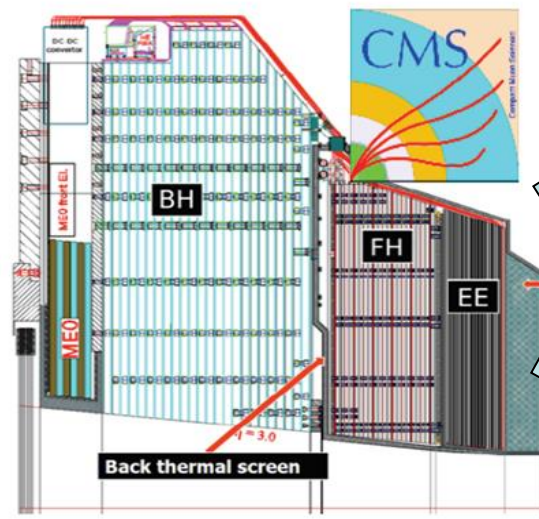
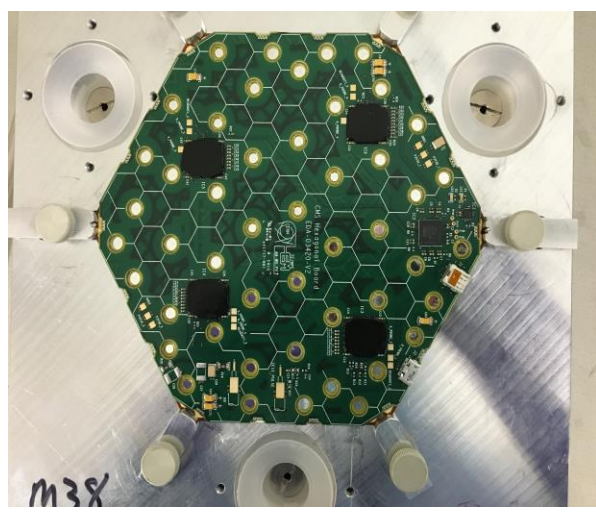
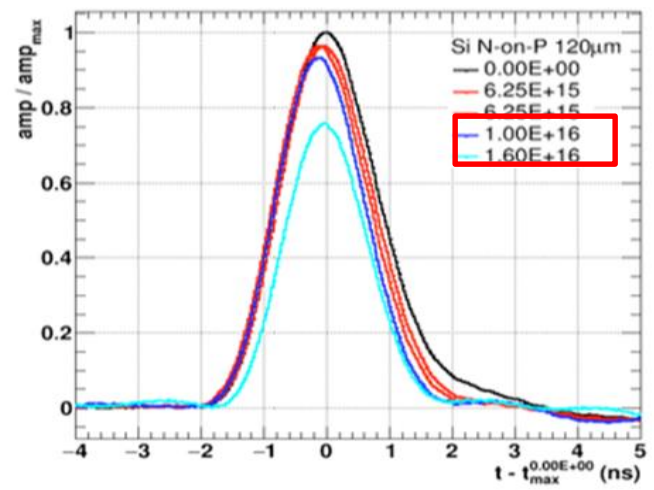
Whole calorimeter will be operated at -30°C



CMS High granularity calorimeter



- **5 Dimensional calorimeter with high radiation resistance**
 - **One probe readout per 1cm^3 ;**
 - **Energy resolution: $25\%/\sqrt{E} \oplus 1\%$;**
 - **Time resolution : 50ps ;**
 - **Radiation tolerance : $1 \times 10^{16} \text{ 1MeV neq/cm}^2$**



HGAL module is key component

Modules production as a core contribution to the CMS Phase 2 upgrade

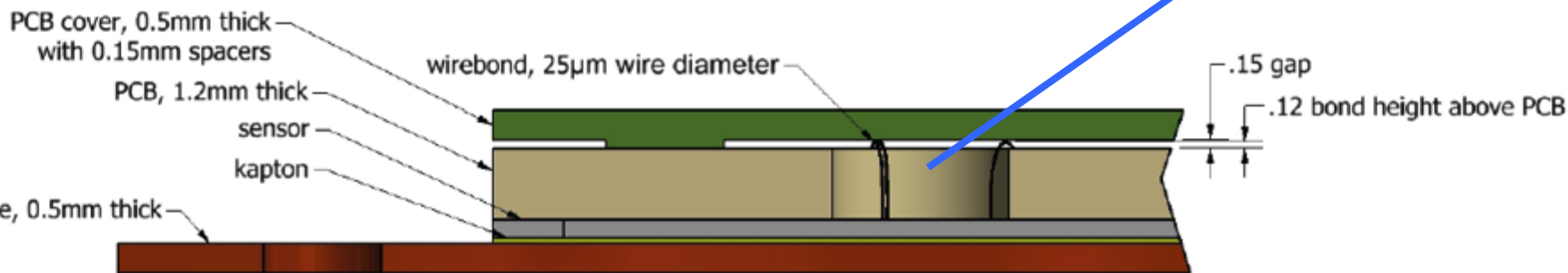
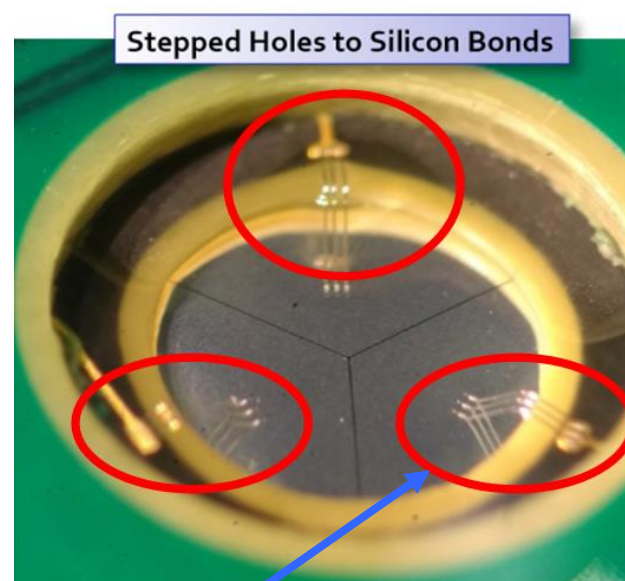
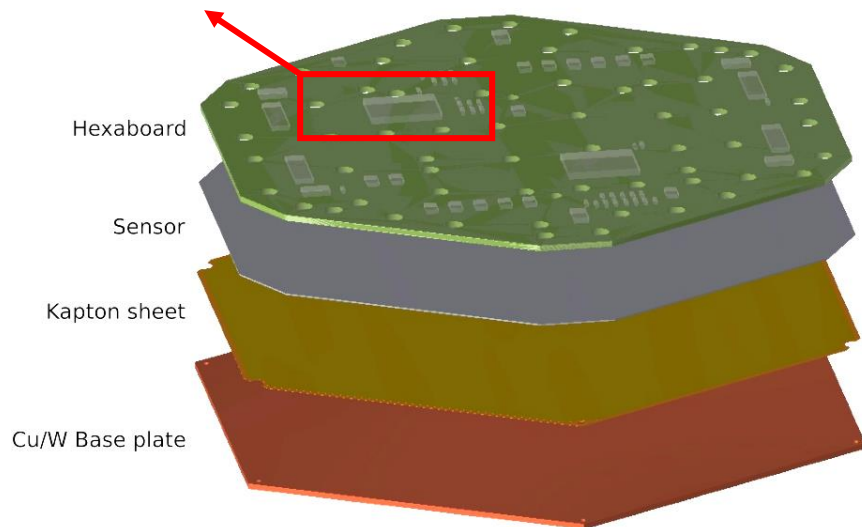


Silicon Detector Module Design of HGCal

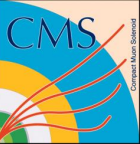


Structure: Base plate, Kapton, Si-sensor, PCB with chips, wirebond for readout

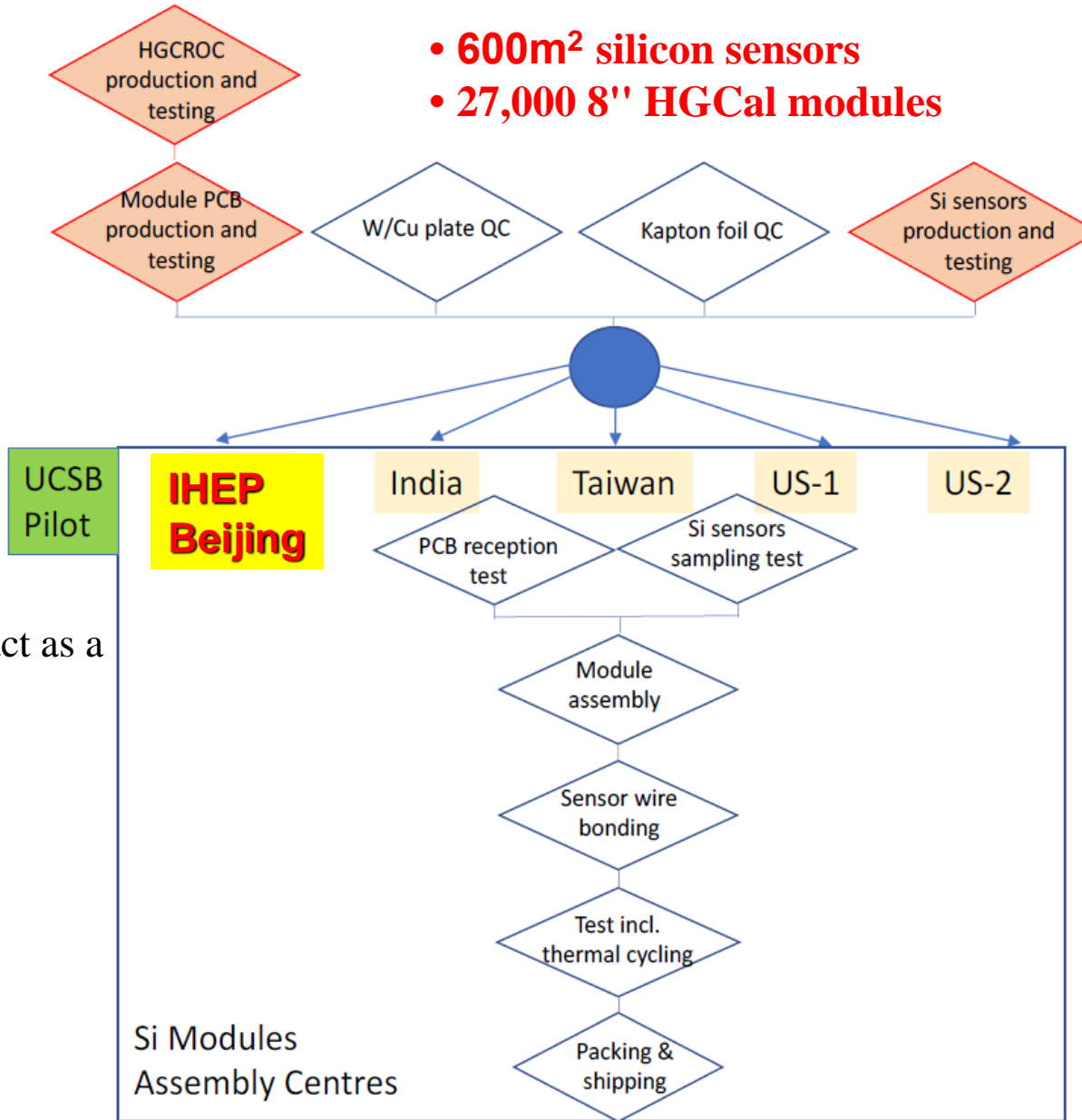
ASIC (130 nm) export license!!!



Compact detector design



Modules production workflows



- **600m² silicon sensors**
- **27,000 8" HGCal modules**

Task hard

- Continuous production for more than 200 days

Requirements of assembly

- Alignment of each layer of module
- Thickness of glue is $50\mu\text{m} \pm 10\mu\text{m}$
- Coverage area $\geq 70\%$
- Three wire bonding per pixel
- Pull strengths $\sim 0.1\text{N}(10\text{g})$

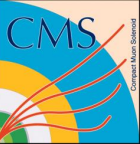
Expensive

- 10,000RMB for each silicon sensor

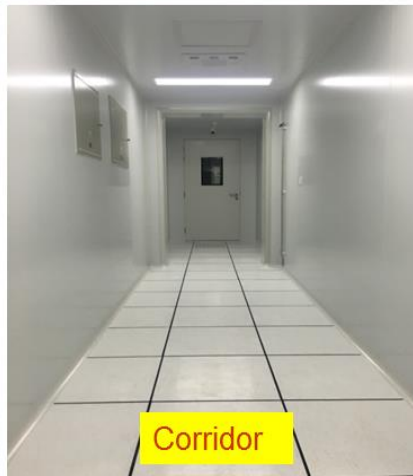
UCSB will act as a pilot centre.

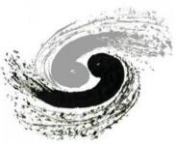


Clean room @ IHEP

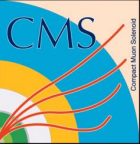


- **Clean room with class 1000**
 - **140 m²**
 - **Temperature is between 20°C to 22°C**
 - **Humidity is between 35% to 55%**
 - **Ground is Anti-static**





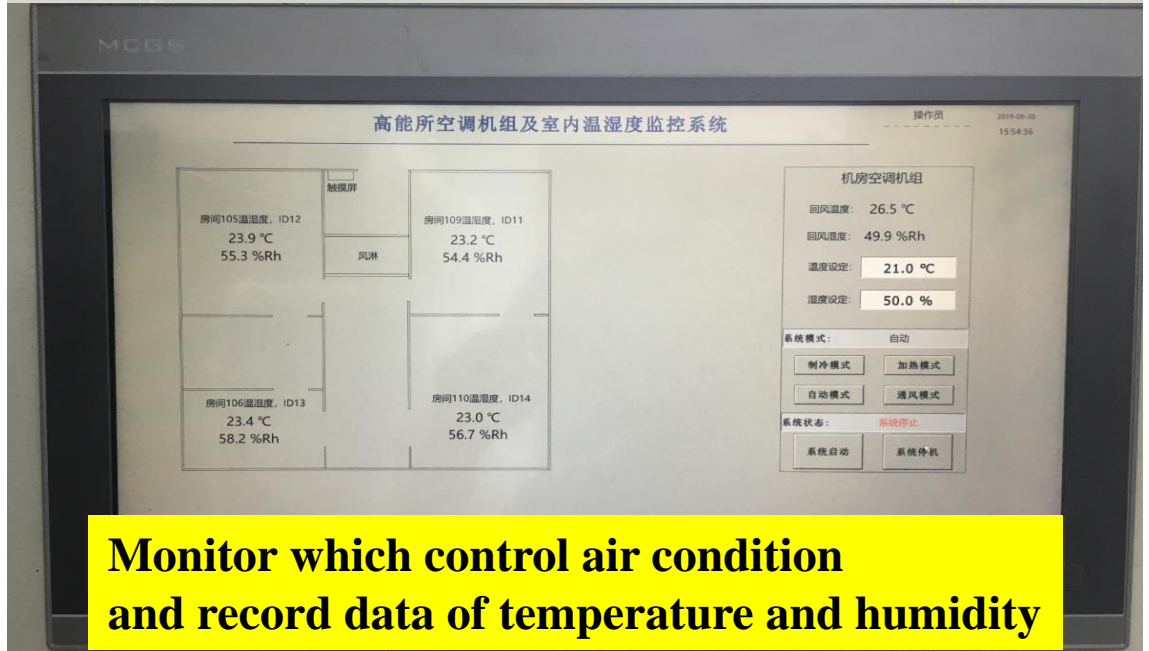
Clean room @ IHEP



- Clean room with class 1000
 - Camera in each room and corridor
 - Temperature and humidity in each room record by sensor



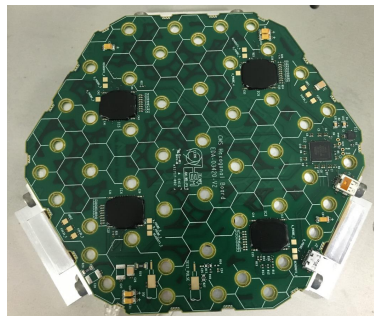
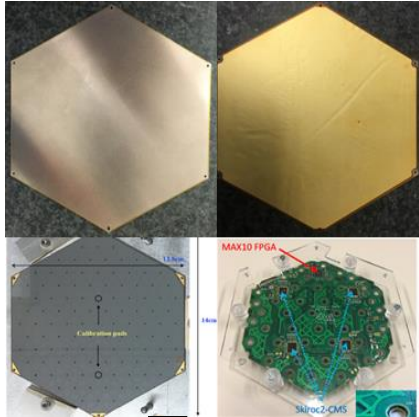
Temperature and humidity sensor



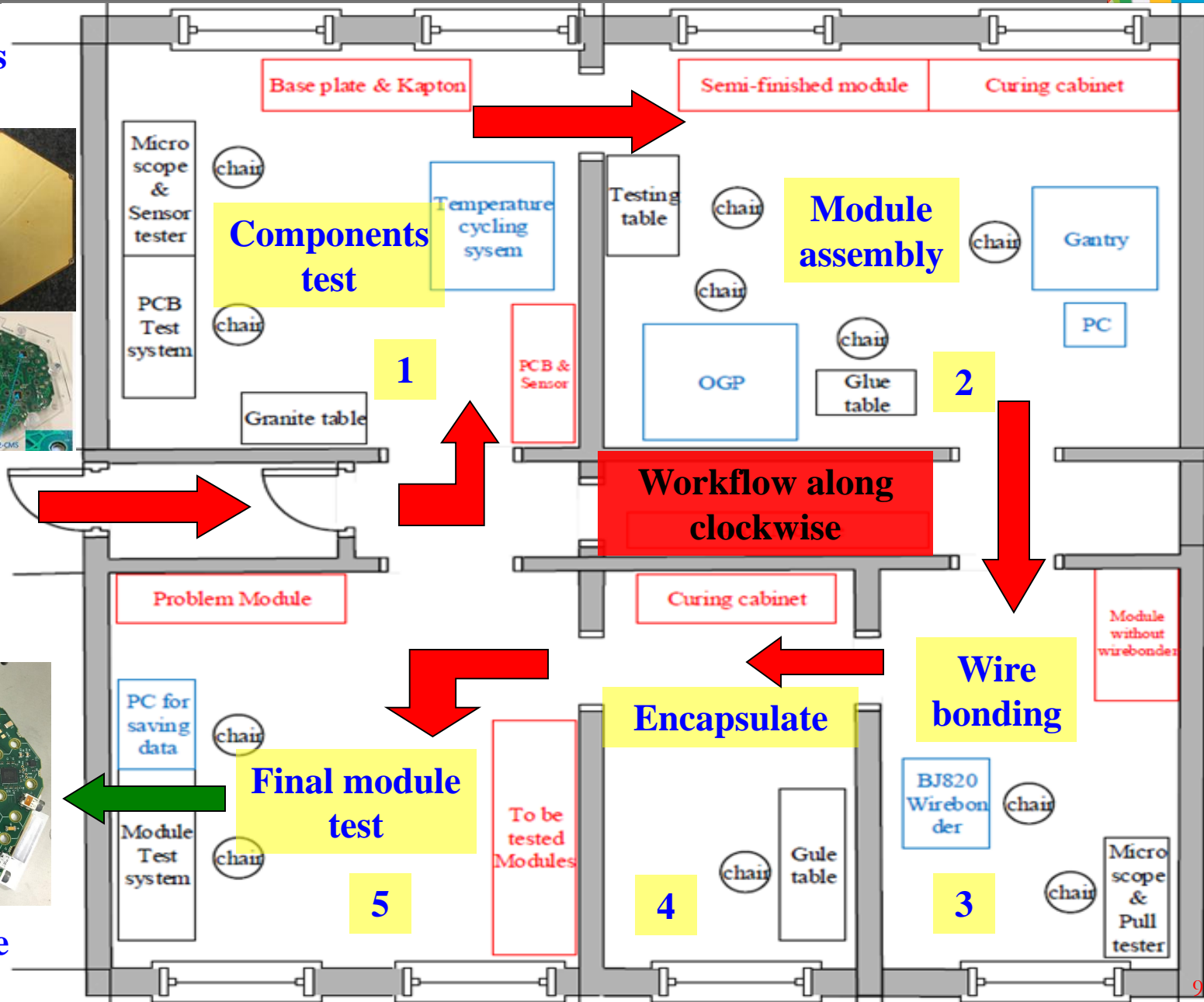


Modules production workflows

Components of module

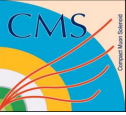


HGCal module





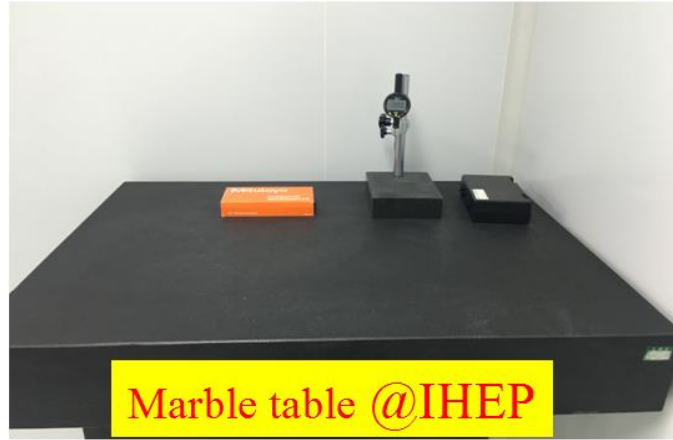
Status of MAC setup @IHEP



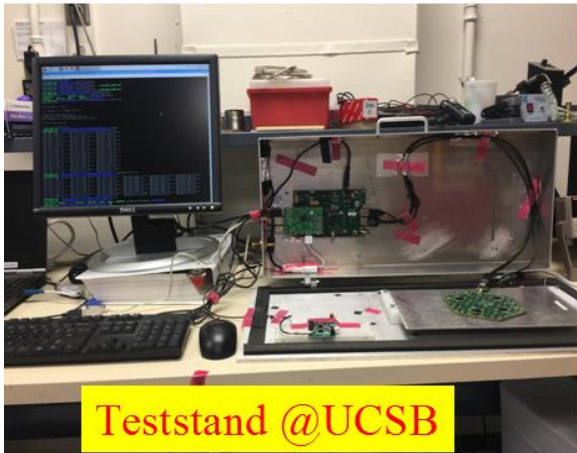
- **Component test before HGCal module assembly**
 - Tooling flatness check Tolerance of flatness should be less than $10\ \mu\text{m}$
 - Component flatness check, especially for baseplate (CuW)
 - Si sensor sampling test
 - PCB reception test for pedestal noise and so on.
 - Save the data to database



Tooling test @UCSB



Marble table @IHEP



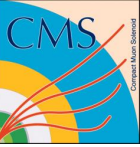
Teststand @UCSB



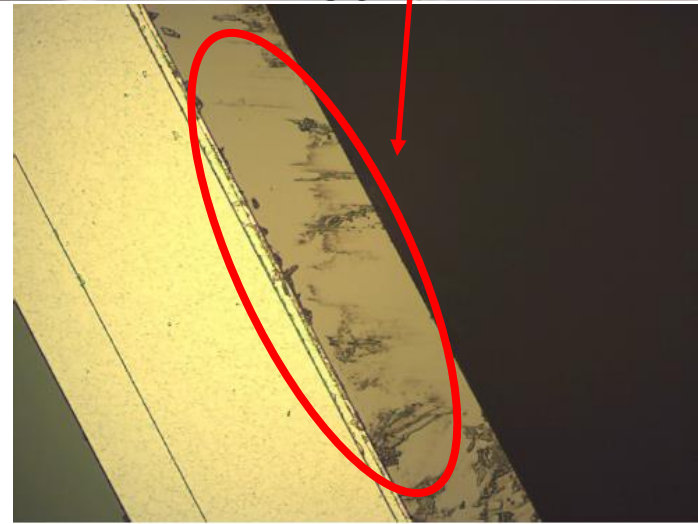
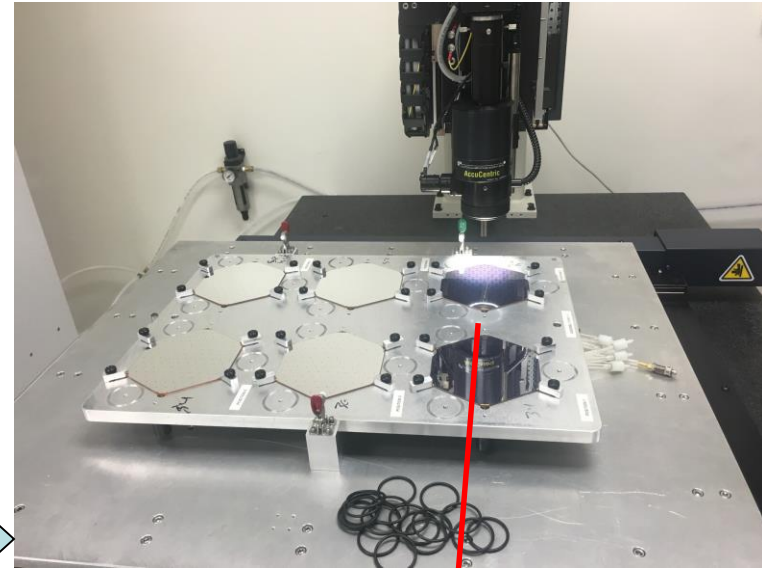
Teststand @IHEP



Status of MAC setup @ IHEP

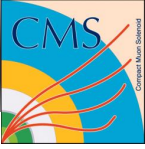


- **Sensor inspection with OGP before assembly**
 - Pick out samples that are not damaged
- **OGP will arrival to IHEP in December**

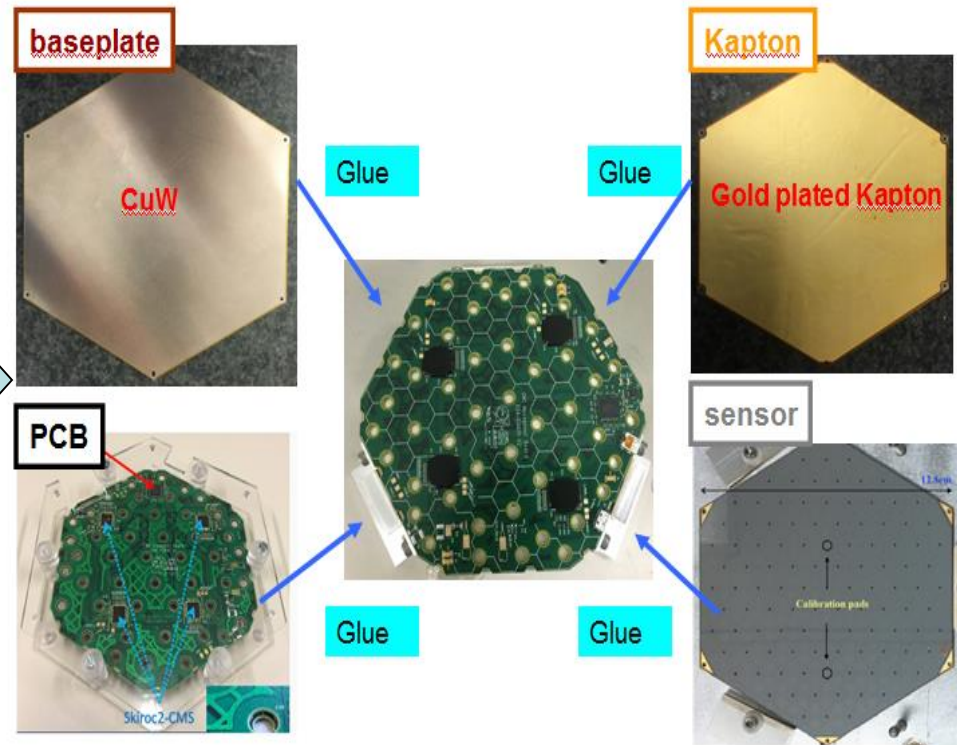
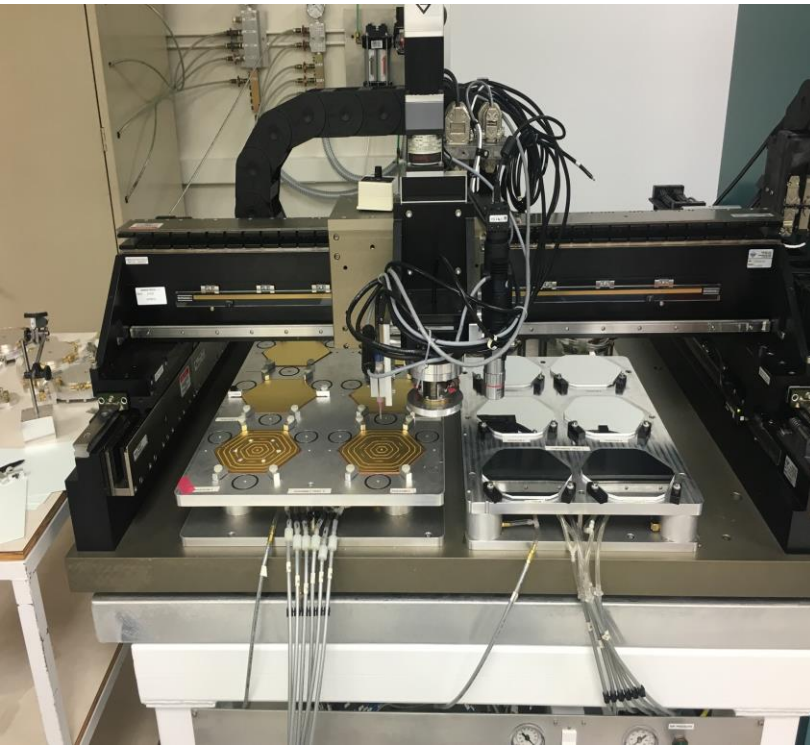




Status of MAC setup @IHEP



- **Glue dispense for HGCal module assembly**
 - Dispense glue in each layer of module by gantry system
- **Gantry will arrival to IHEP in the end of this year**

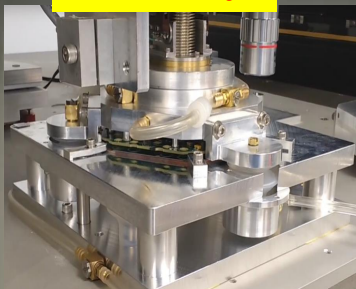


Gantry @UCSB



Status of MAC setup @ IHEP

Assembly



Storage



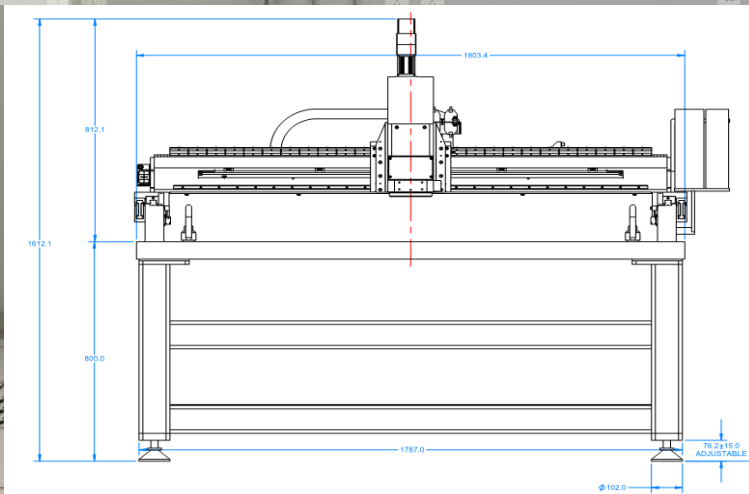
Clean and dry air

Glue dispense



Vacuum

High pressure gas

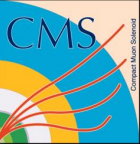


XY axis travel: 1250mm × 1250mm;
XY axis accuracy: ±5μm;
Z axis travel: 100mm,
Z axis accuracy: ±2μm;
U axis travel: 360 degree

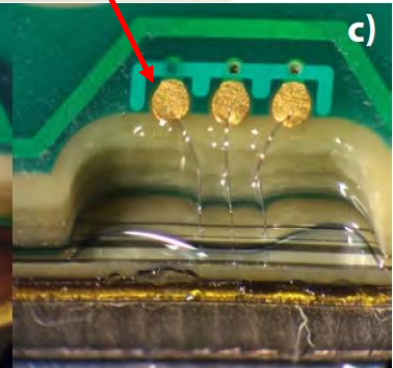
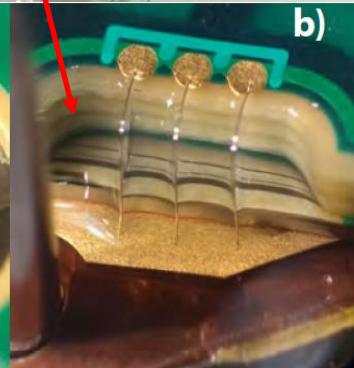
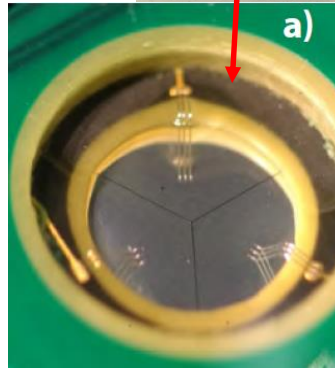
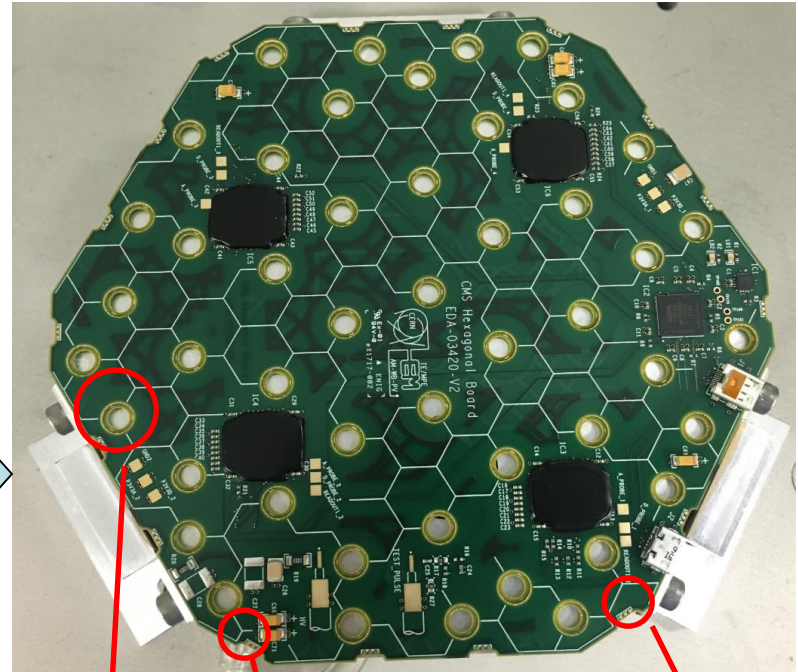




Status of MAC setup @IHEP



25 μ m aluminum wire with about pull strengths of 10 grams



High Speed Fully Automatic Fine Wire Wedge Bonder @IHEP

front-end electronics

back-plane biasing of sensor

guard ring



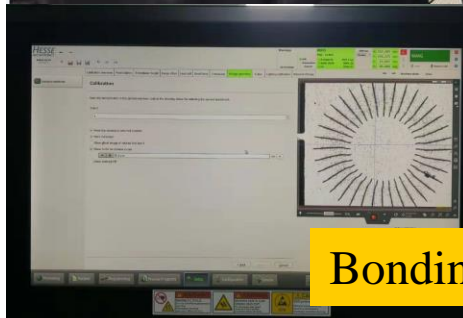
Status of MAC setup @IHEP



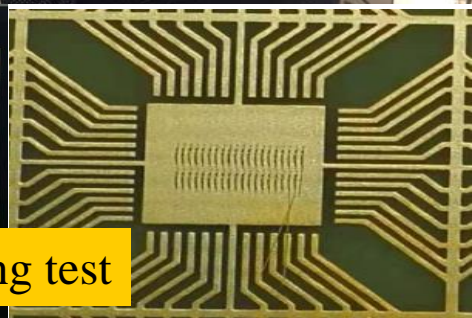
Fixing pedestal for 6" module



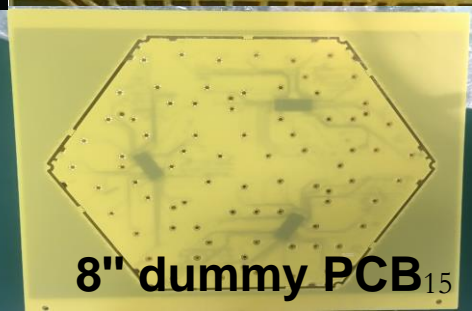
Training



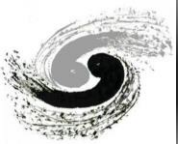
Bonding test



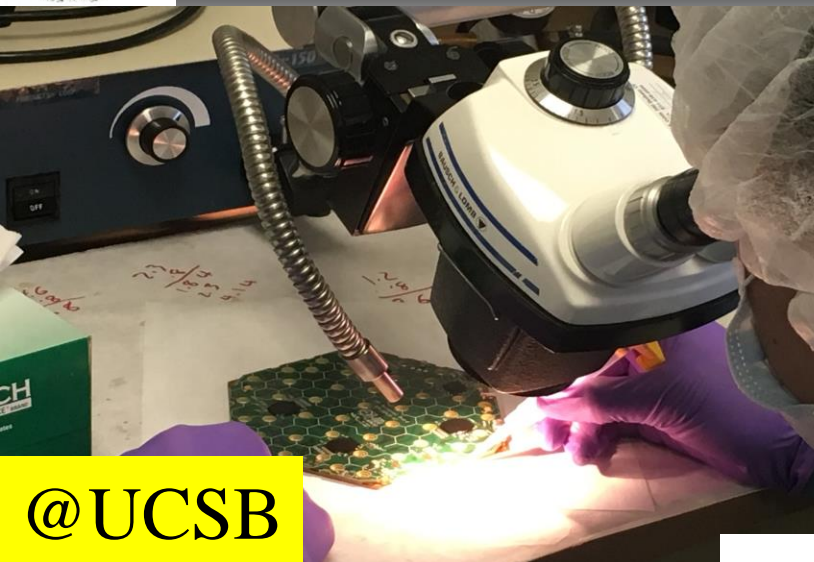
8" dummy sensor



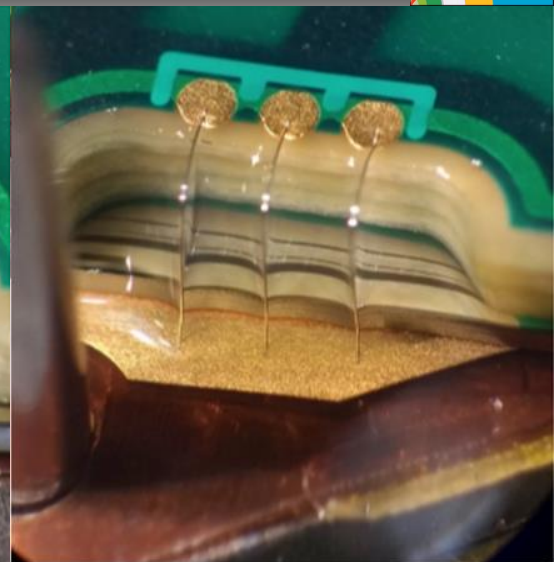
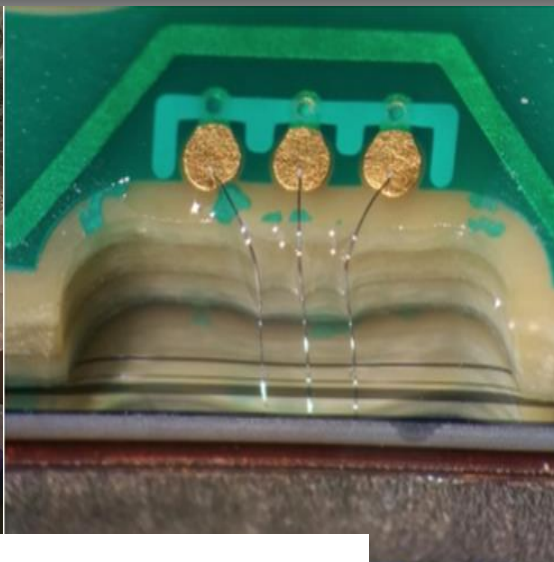
8" dummy PCB₁₅



Status of MAC setup @IHEP



@UCSB

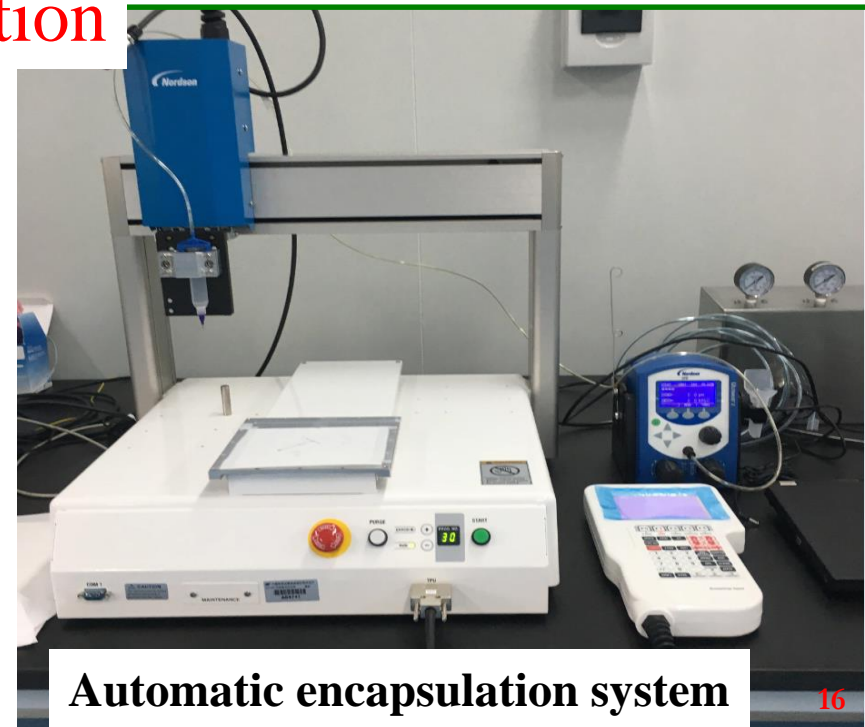


Encapsulation



@IHEP

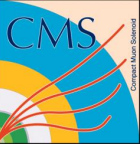
Encapsulation room



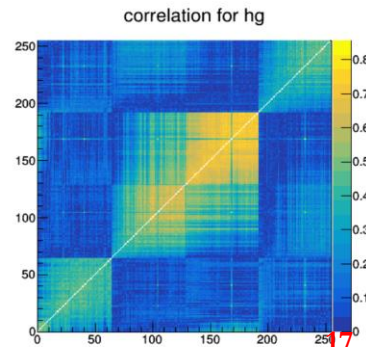
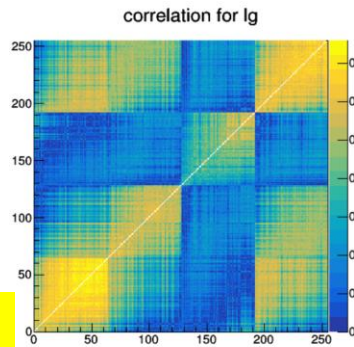
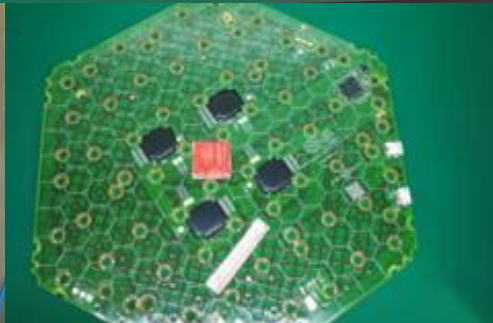
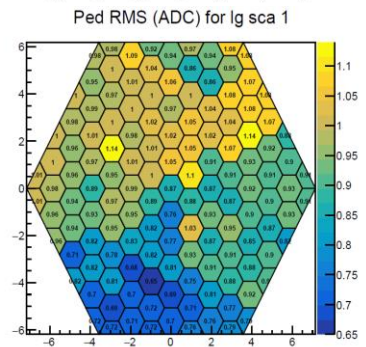
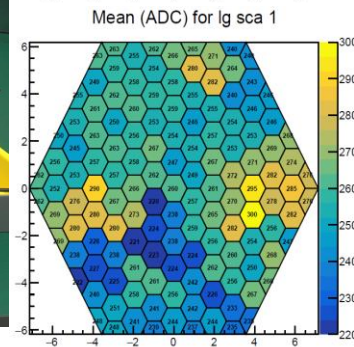
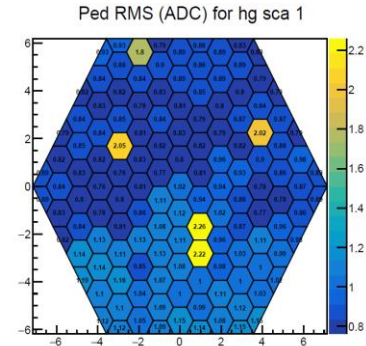
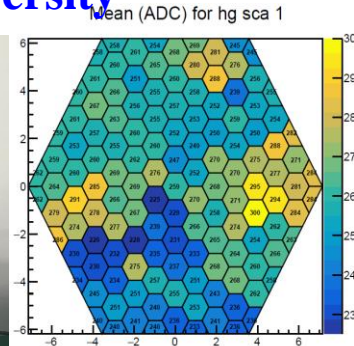
Automatic encapsulation system



Status of MAC setup @IHEP



- **Test for HGCal module**
 - Three HGCal modules arrived at IHEP.
 - Teststand has been setup.
 - Part of devices are supported by Tsinghua University

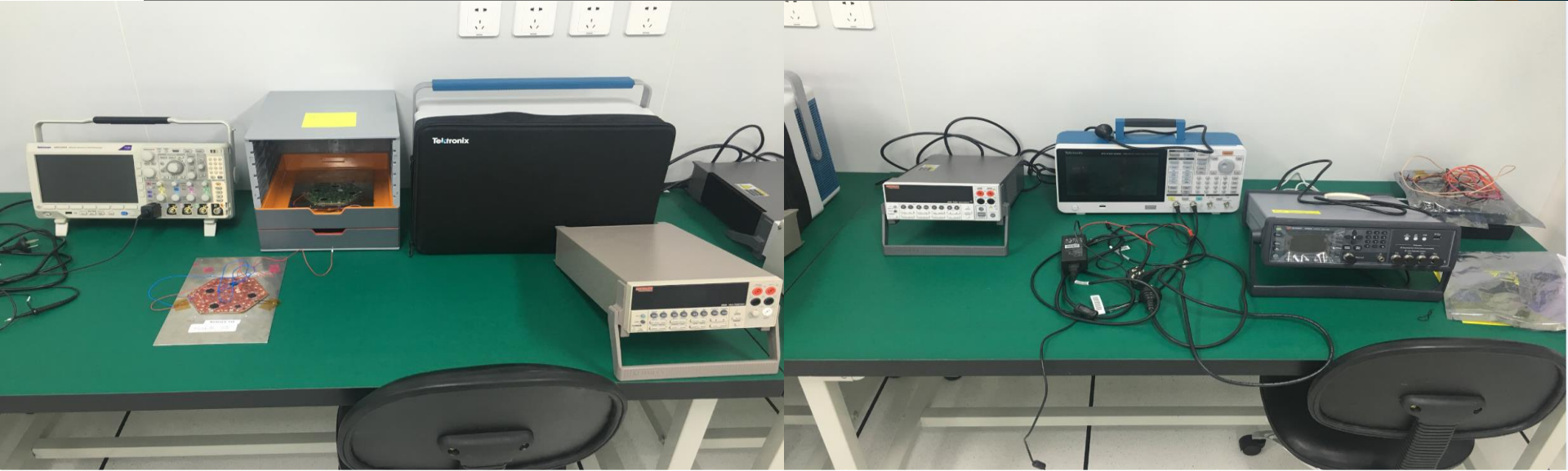
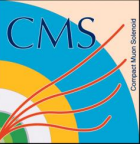


6" module

8" PCB



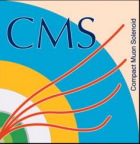
Status of MAC setup @IHEP



AFG3100 function generator	Arrival	Support By Tsinghua University
Keysight E4980AL LCR	Arrival	
ORTEC multi-channel Analyzer	Delivery	
ORTEC Preamplifier	Delivery	
NIM 8301	Delivery	
CAEN HV power supply	Delivery	
Oscilloscope	Arrival	
Keithley 2410 source meter	Arrival	
Kethley 2000e multimeter	Arrival	
.....	

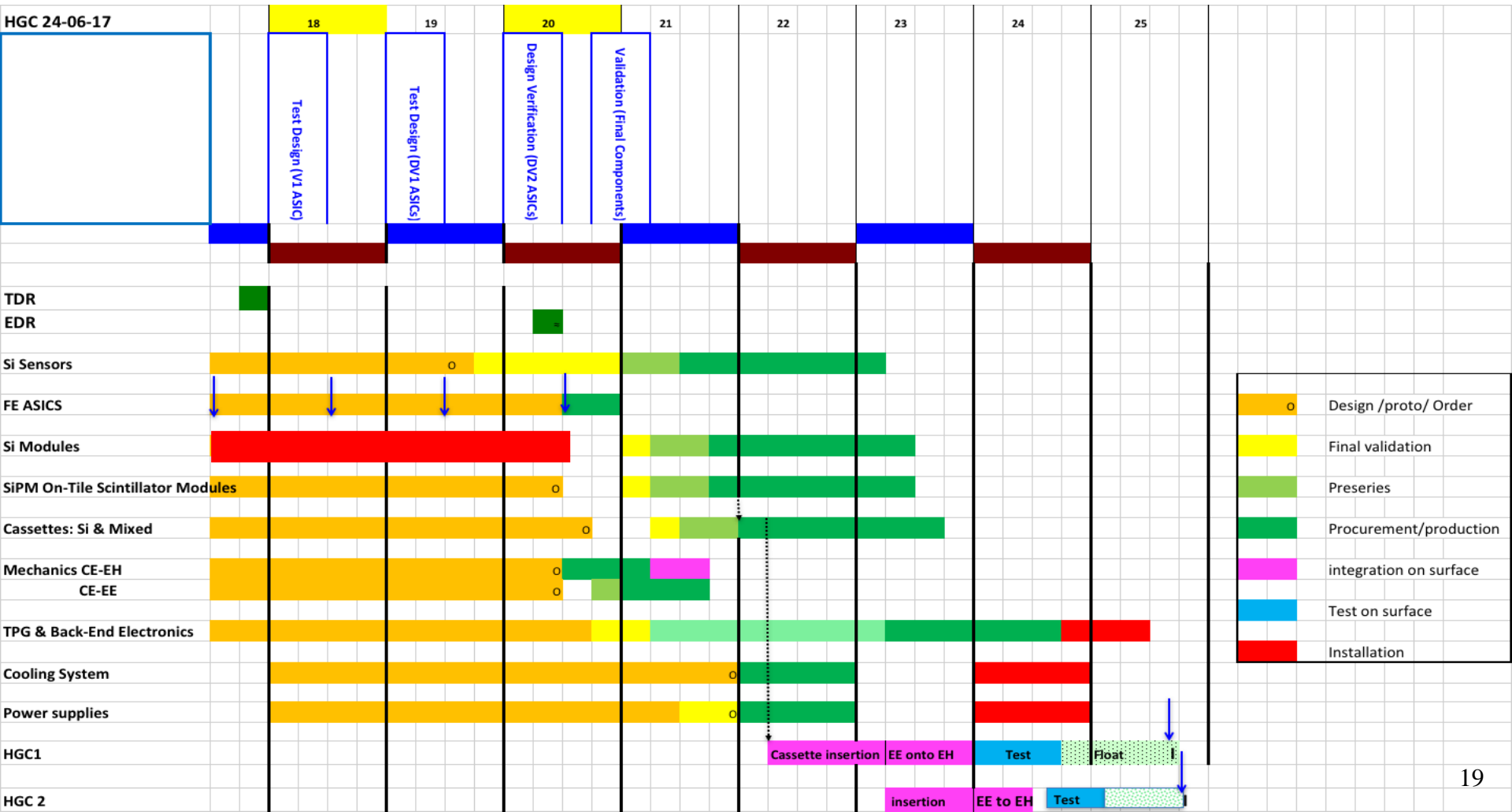


Time line



- **Upgrade time line**

- **2020: MAC needs to complete quality control certification**
- **2021—2023: HGCal module mass production**
- **2024—2025: Install HGCal on CMS**





- **MAC setup @ IHEP in next step:**

- **Equipment purchase**

- **Gantry** (Aerotech AGS10000)
- **Tool**
 - 9 module assembly plates
 - 26 sensor pickup tools
 - 26 PCB pickup tools
 - 2 sensor supply plate
 - 2 PCB supply plate
 - 1 gantry assembly plate base with vacuum posts and fittings
 - 1 gantry pickup tool base
 - 2 fixed pickup tooling on the gantry
 - Pneumatic valves for vacuum chuck and vacuum pump
- **Glue dispensing**
 - Air compressor
 - Nordson EDF glue dispensing system for gantry
- **Vacuum**
 - FESTO valves and sensors
- **Vision**
 - CCD system
- **Software**
 - Labview software
 - NI-Vision Assistant software

- **Module assembly with dummy components:**

dispense glue  wire bonding  encapsulate

- **Assembly real modules for quality control certification**

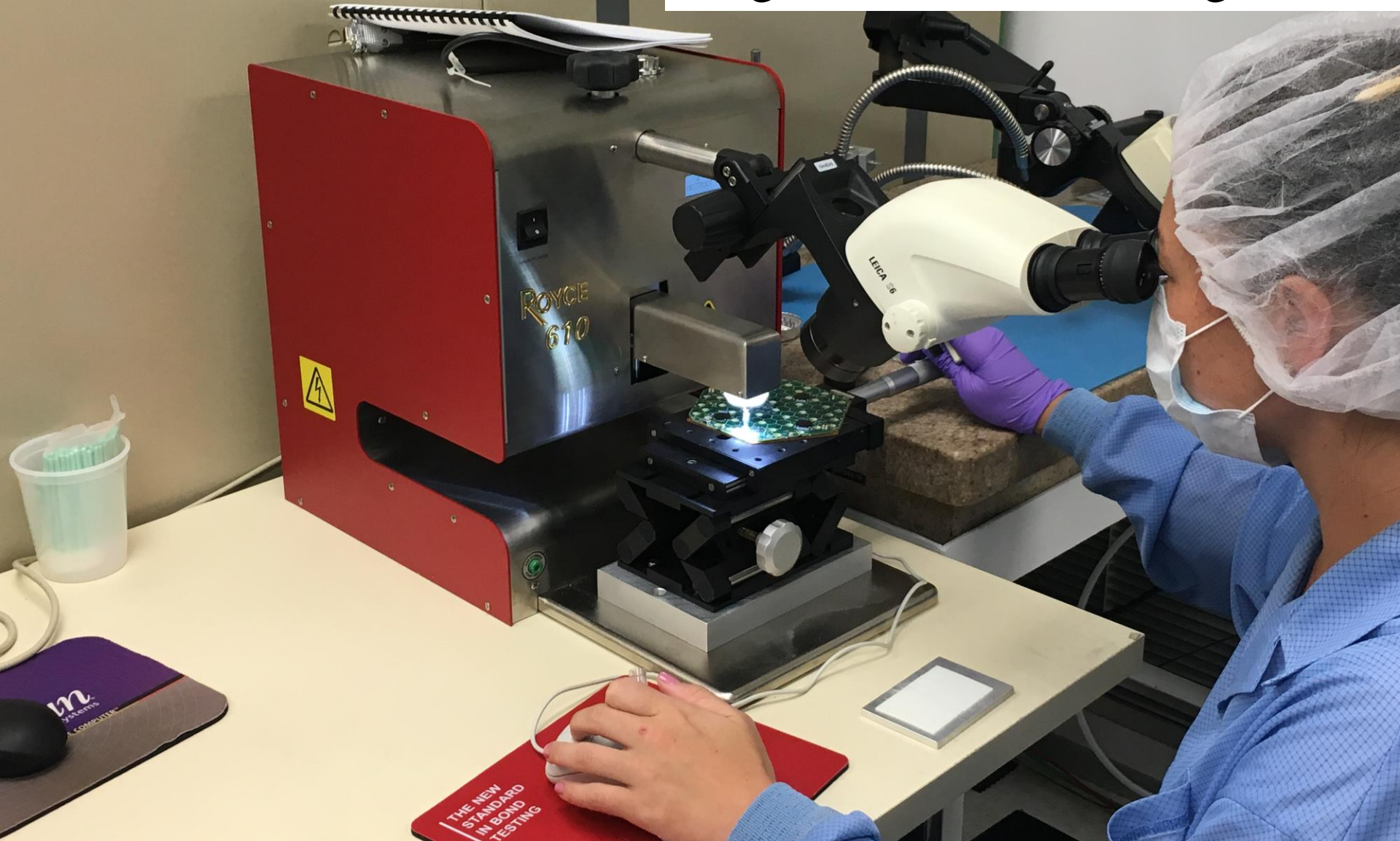
Thanks

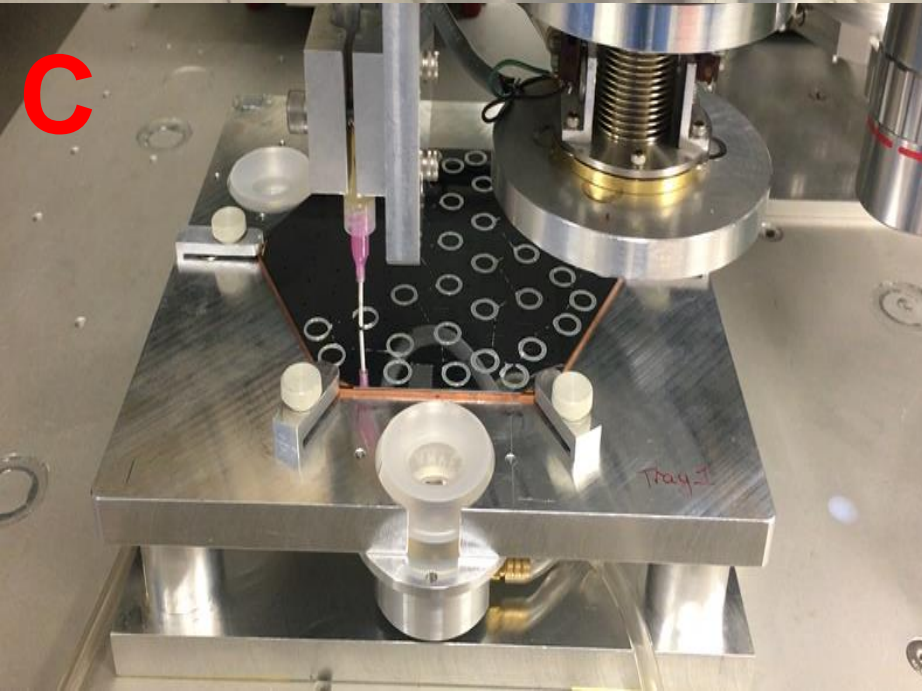
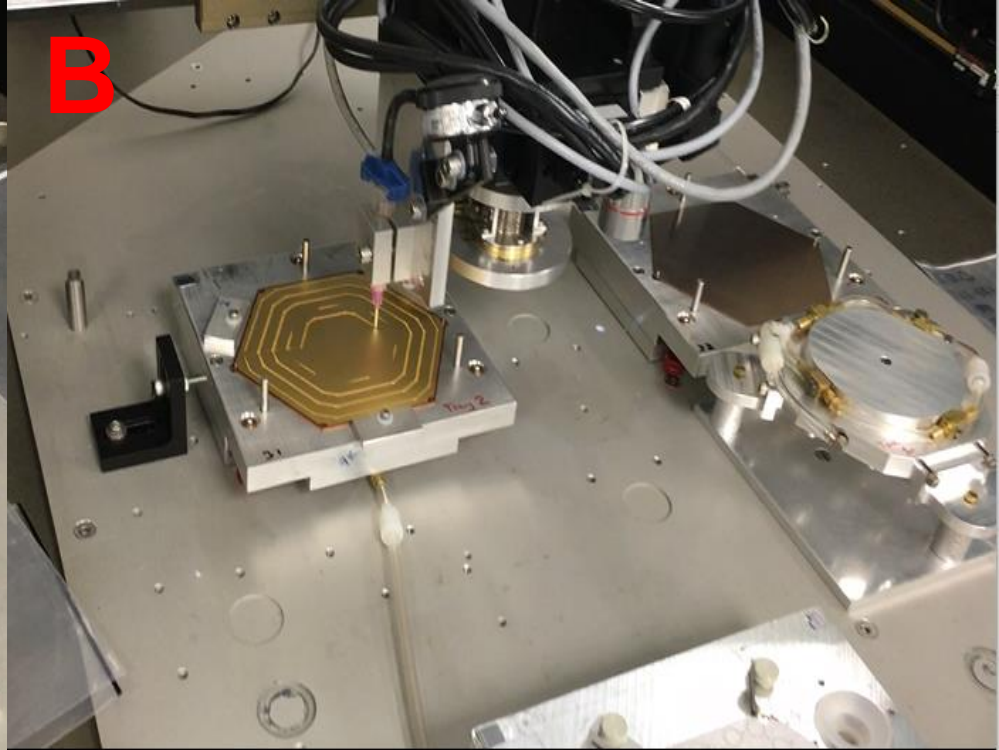
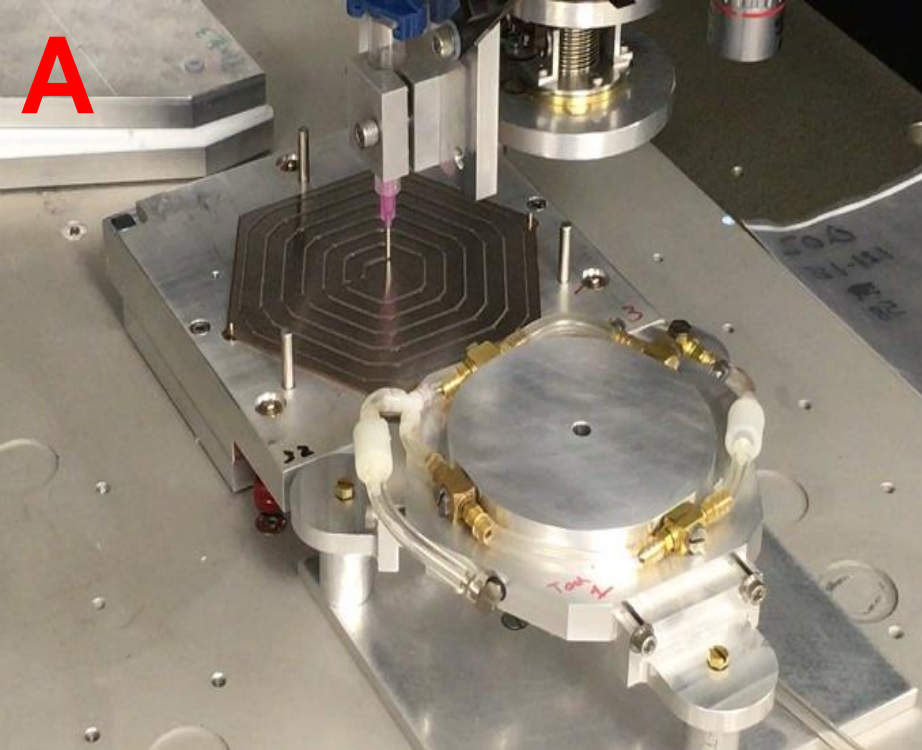


Back up

Pull Tester

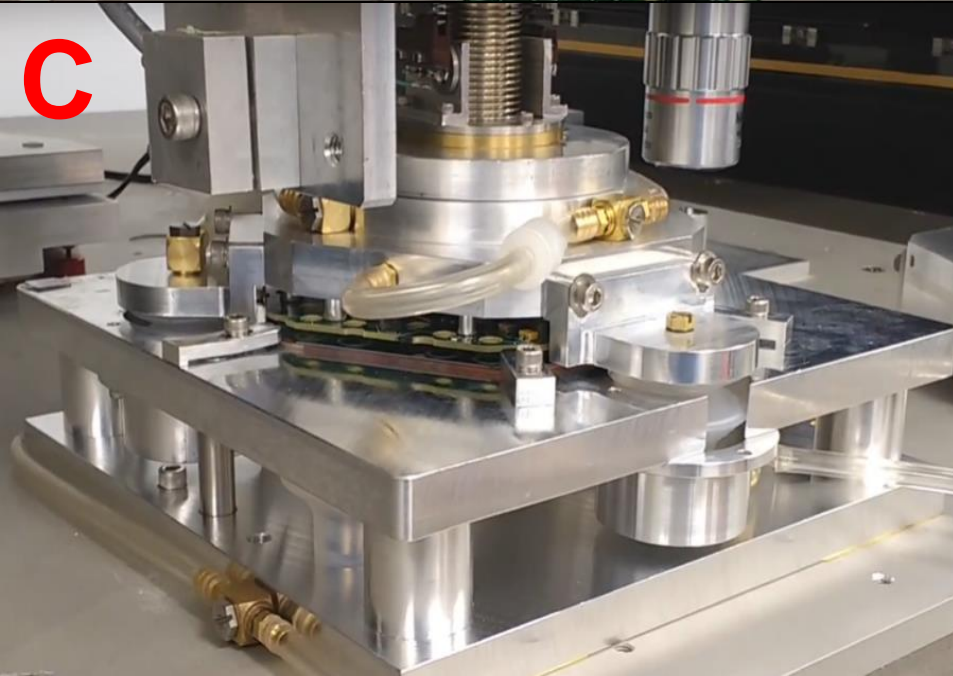
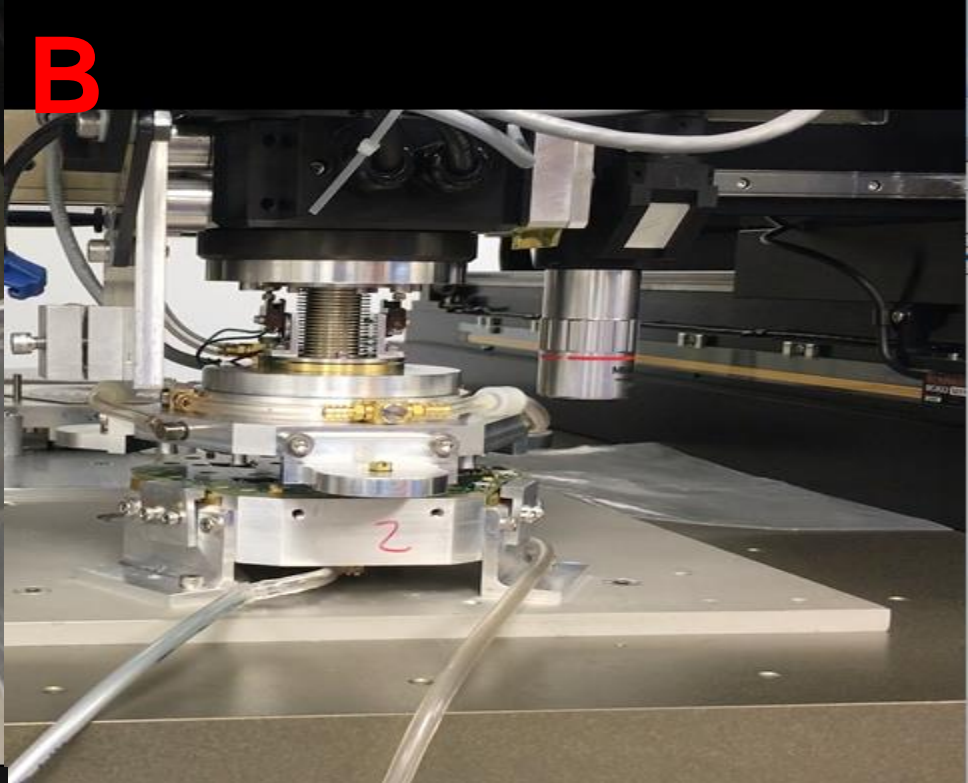
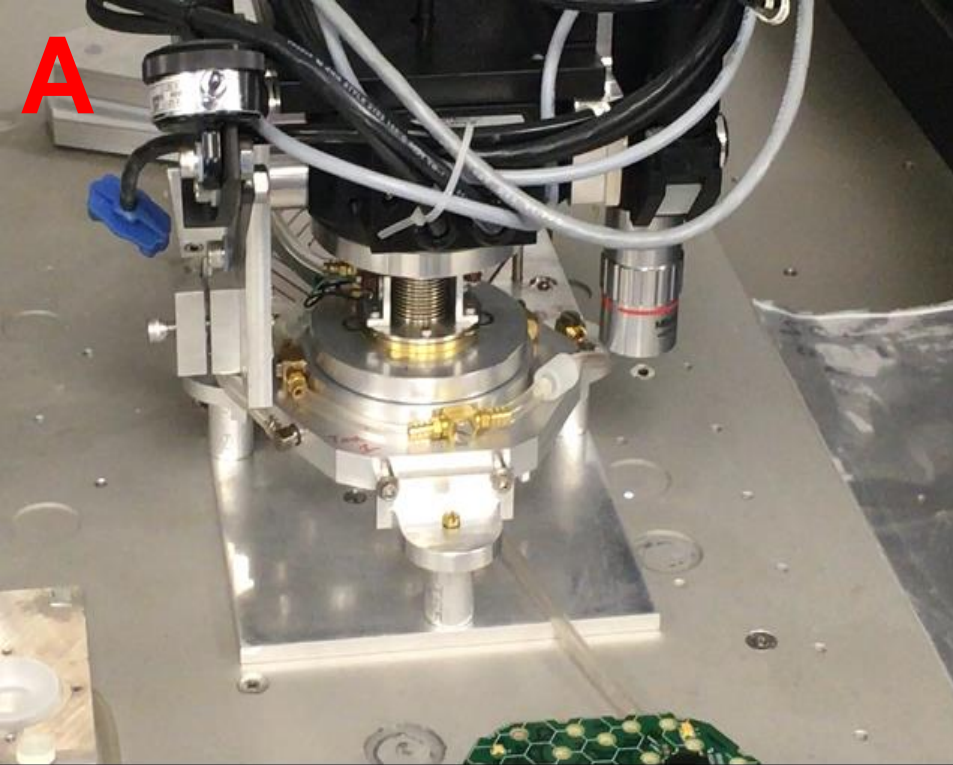
Pull strengths
Stepped bonds – 10 grams
Edge bonds – 10 grams





- A.** Dsipense glue on the tungsten plate.
- B.** Dsipense glue on the kapton.
- C.** Dsipense glue on the silicon sensor.

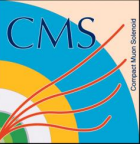
All of these process of dispense glue can be executed in one time



- A.** Gantry pick up the tool from #3 pedstal
- B.** Using this pick-up tool to pick up the PCB hexboard from #5 pedstal.
- C.** Put the hexboard on the level 3 board by using this pick-up tool

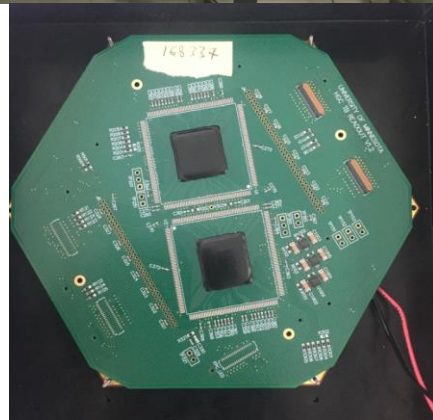
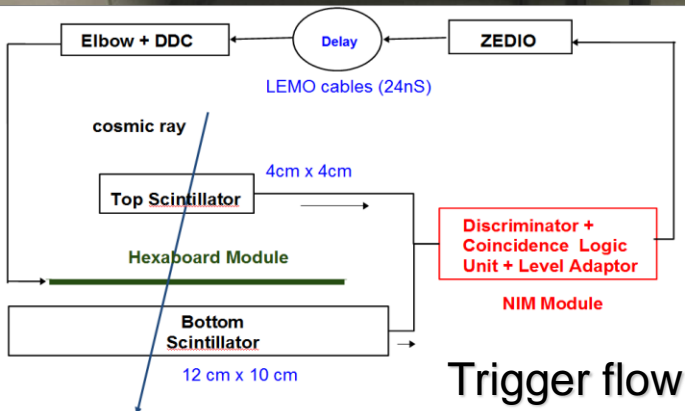
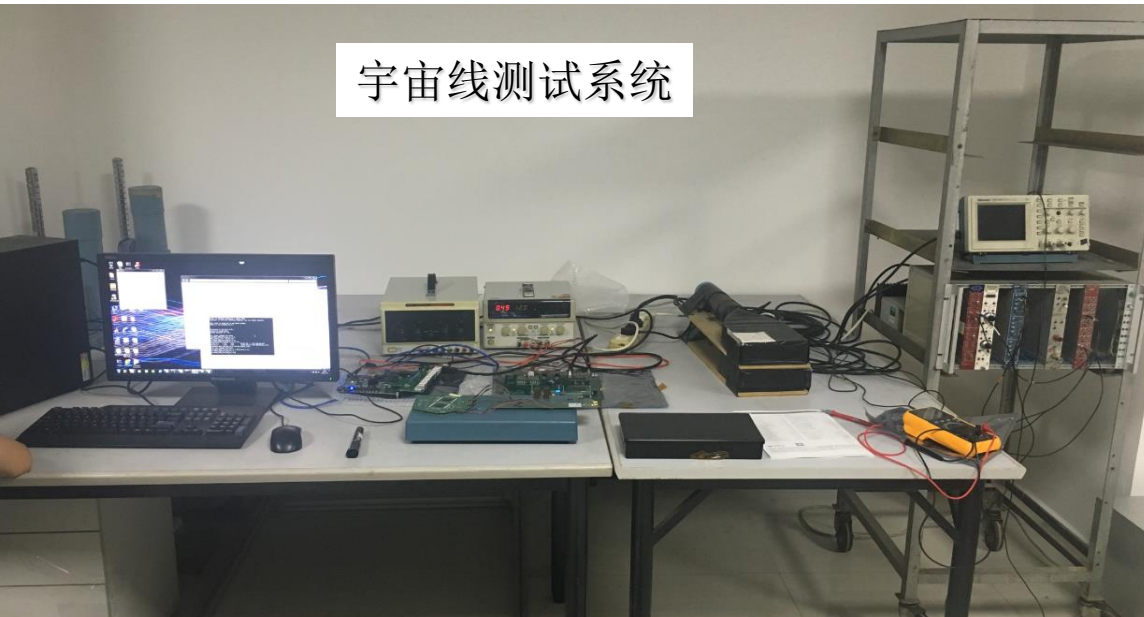


HGCAL cosmic ray test @ IHEP

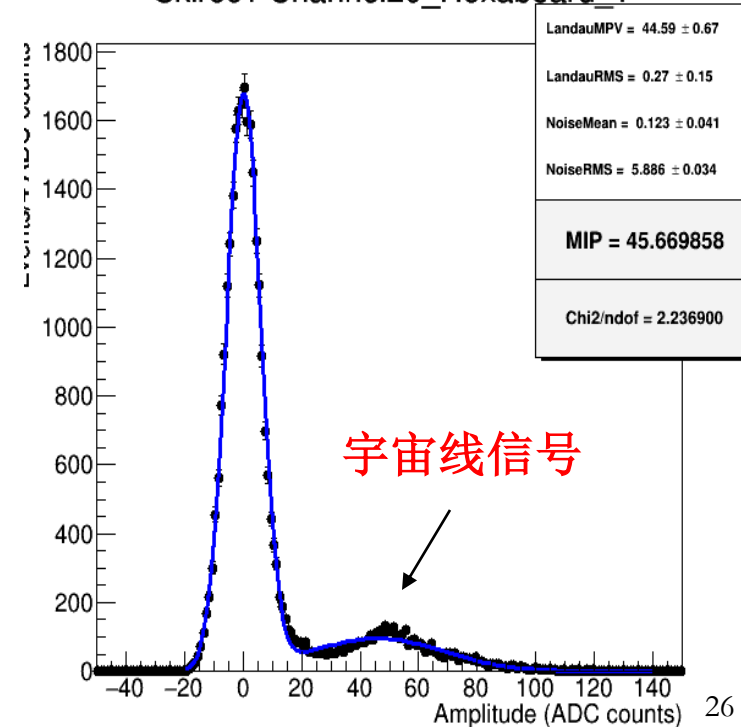


- **首次**在**高能所**搭建**HGCAL宇宙线测试平台**
 - **2018年7月**HGCAL宇宙线测试平台以及一块HGCAL模块送达至高能所
 - **2018年8月**首次在高能所完成HGCAL宇宙线测试工作
 - 为**2019年**在高能所做HGCAL束流测试做准备

宇宙线测试系统



Skiroc1 Channel20_Hexaboarad_1



Test beam from 2016 to 2017

Date	Location	No. of module	PCB type	ASIC type	Database	IHEP
2016	FNAL	16 Si modules	“2 layers” PCB	SKIROC 2 ASIC	e beam (4-32 GeV)	✓
2016	CERN	8 Si modules	Single layer PCB (V1)	SKIROC 2 ASIC	e beam (20-250 GeV) π beam (125 GeV)	✓
8-15May 2017	CERN	1 Si module	Single layer PCB (V1)	SKIROC 2CMS ASIC	e beam (20-250 GeV)	✓
12-19 July 2017	CERN	10 Si modules	Single layer PCB (1 V1 & 9 V2)	SKIROC 2CMS ASIC	e beam (80 GeV) π beam (300 GeV)	✓
29 Sep-2 Oct 2017	CERN	17 Si modules	Single layer PCB (1 V1 & 16 V2)	SKIROC 2CMS ASIC	e beam (20-90 GeV) hadrons beam (100-350 GeV)	✓
19-23 October 2017	CERN	20 Si modules	Single layer PCB (1 V1, 16 V2 & 3 V3)	SKIROC 2CMS ASIC	e beam (20-80 GeV) hadrons beam (50-120 GeV)	✓
2017 From July to October	AHCAL is also tested together with HGCAL 12 active layers 144 scintillator tiles (each 3 mm thick) of 3×3 cm ² Readout by SiPM					✓



中国科学院高能物理研究所

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CMS HGCAL Beam Tests

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China LHC Physics Workshop at DLUT, Dalian, Oct. 24-27, 2019

