CuW baseplate R&D and production

Hao Zhu (IHEP)

On behalf of Chinese HGCal Group

Oct 31rd, 2025

CLHCP 2025, Xinxiang

Outline:

1. CuW baseplate introduction & production status

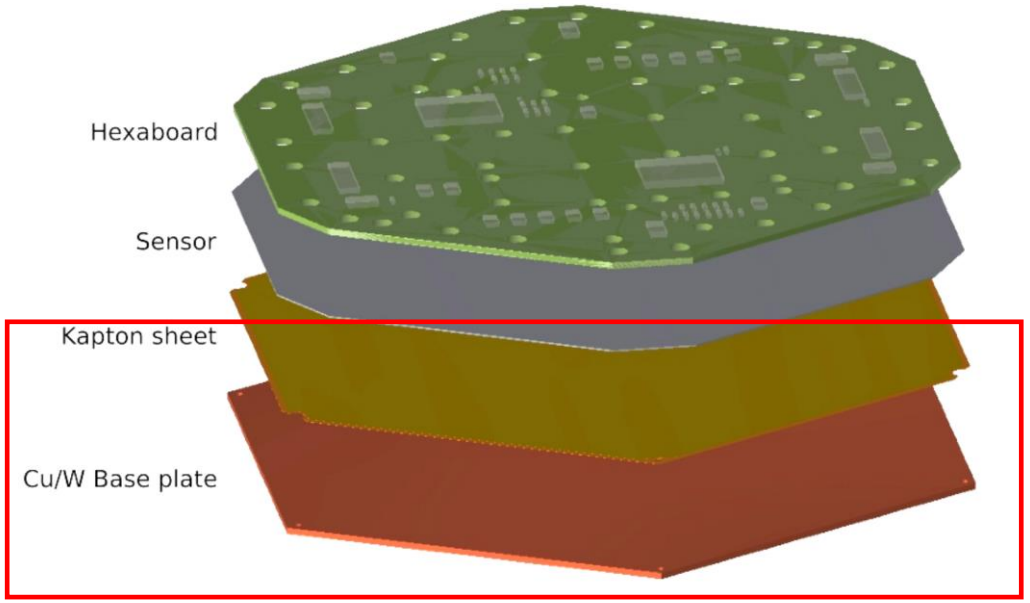
2. Irradiation test, peel test, mechanics study, heat flow study and specs inspection for IHEP baseplates

3. Future production plan

CuW baseplate introduction & production status

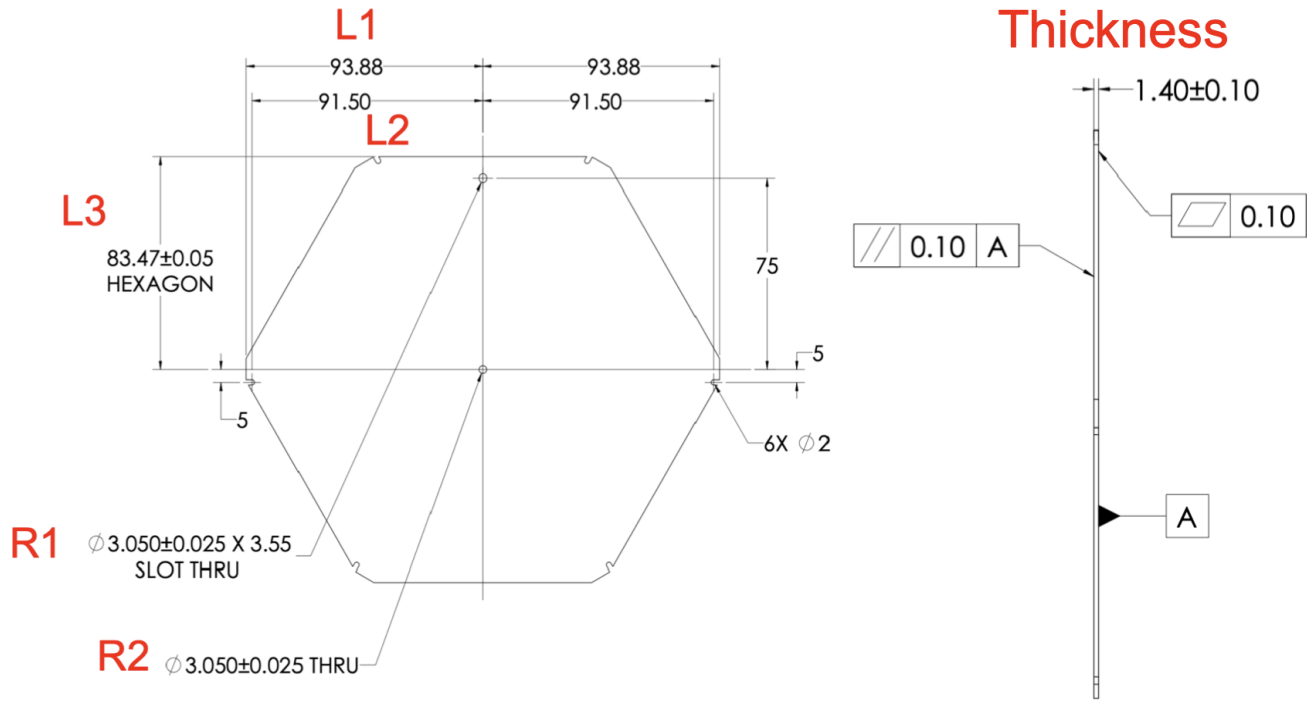
CuW baseplate introduction

- CuW baseplate in HGCal: will be used in ECal; insulation layer, absorber, thermal conductive layer, sensor protection, noise shelding, supporting.
- 2 Kapton assembly process(bonding Kapton and CuW): KIT plan, IHEP plan.
- First time Chinese entities participate and will produce the largest area(~90%) of CuW baseplates.
- Brought in orders worth over 10 million RMB for China's precision machining industry.
- Participating entities: IHEP, THU, ZJU, FDU, NNU.



Complete HGCal module

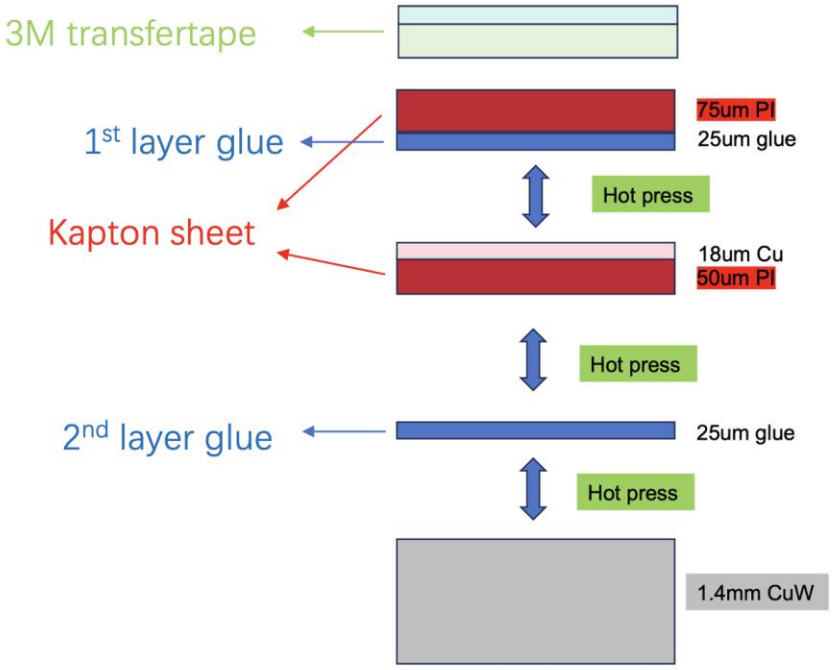
Complete CuW baseplate



CuW baseplate design

Introduction of KIT plan and IHEP plan

- IHEP Kapton assembly process
  - Using hot melt adhesive to bond different layers.
  - Glue fully covers entire CuW baseplate.
  - Layers bonded together by hot pressing process.
  - Will cover most of the production work



- KIT Kapton assembly process
  - Hybrid attachment with 3M glue and epoxy.
  - Using gantry in KIT's lab to dispense glue on CuW baseplate.
  - Use partially-overlapping glue dispensing pattern.
  - Laminate using pressure.
  - Will take on production partially

KIT plan's glue pattern

p.s. KIT plan will be modified soon.

Comparison & advantage

	KIT plan	IHEP plan	IHEP plan's advantage
Glue dispensing pattern	Partially-overlapping glue dispensing pattern.	Fully-overlapping glue dispensing pattern.	Have larger glue coverage area.
Bonding method	Laminate using pressure.	Hot pressing process.	Better mechanism performance.
Production method	Laboratory production.	Industrial production.	Capable for mass production.
All kinds of test	Irradiation test, lack of mechanical test.	Irradiation test, peel test, mechanical test, etc.	Passed all tests so far.

CuW baseplate production status

3 batches small batch trial production of CuW baseplate produced(81 in total):

- 1st batch,10 CuW baseplates, 2022.09
  - Mainly for all kinds of tests.
- 2nd batch,41 CuW baseplates, 2023.09
  - 13 send to NTU for module assembly.
  - 13 send to UCSB for module assembly.
  - 15 @IHEP for module assembly and test.
- 3rd batch,30 CuW baseplates, 2024.07
  - 7 send to NTU for module assembly.
  - 2 send to CERN for irradiation test and peel test.
  - 8 for IHEP's pre-production modules.
  - 10 for IHEP's pre-series modules.

Full scale production(plan around 12000):

- Pre-batch 1200 bare CuW ready and tested/labeled, next batch 2500 bare CuW have just done manufacture
- Extra 100 bare CuW for KIT ready and tested/labeled, have shipped to CERN.

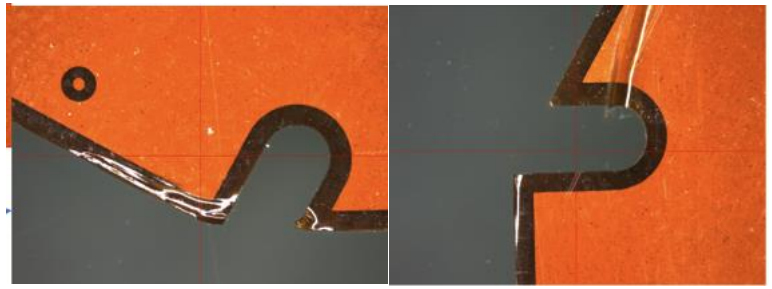
So far, IHEP has produced the most CuW baseplates used for module assembly and testing.

Irradiation test, peel test, mechanics study, heat flow study and specs inspection for IHEP baseplates

Irradiation test

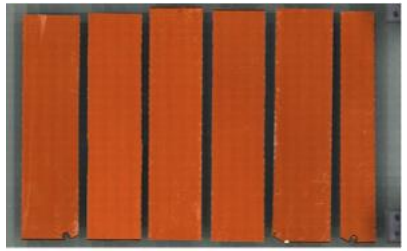
IHEP produced CuW baseplates have undergone 3 rounds of irradiation test and part of peel test.

- 1st round irradiation test
  - 2024.05 @CIEMAT.
  - Integrated dose: 2 MGy.
  - Sample: old version IHEP baseplates(2 layers of different version glue).
  - High humidity(~80/90%)
  - Delamination discovered.



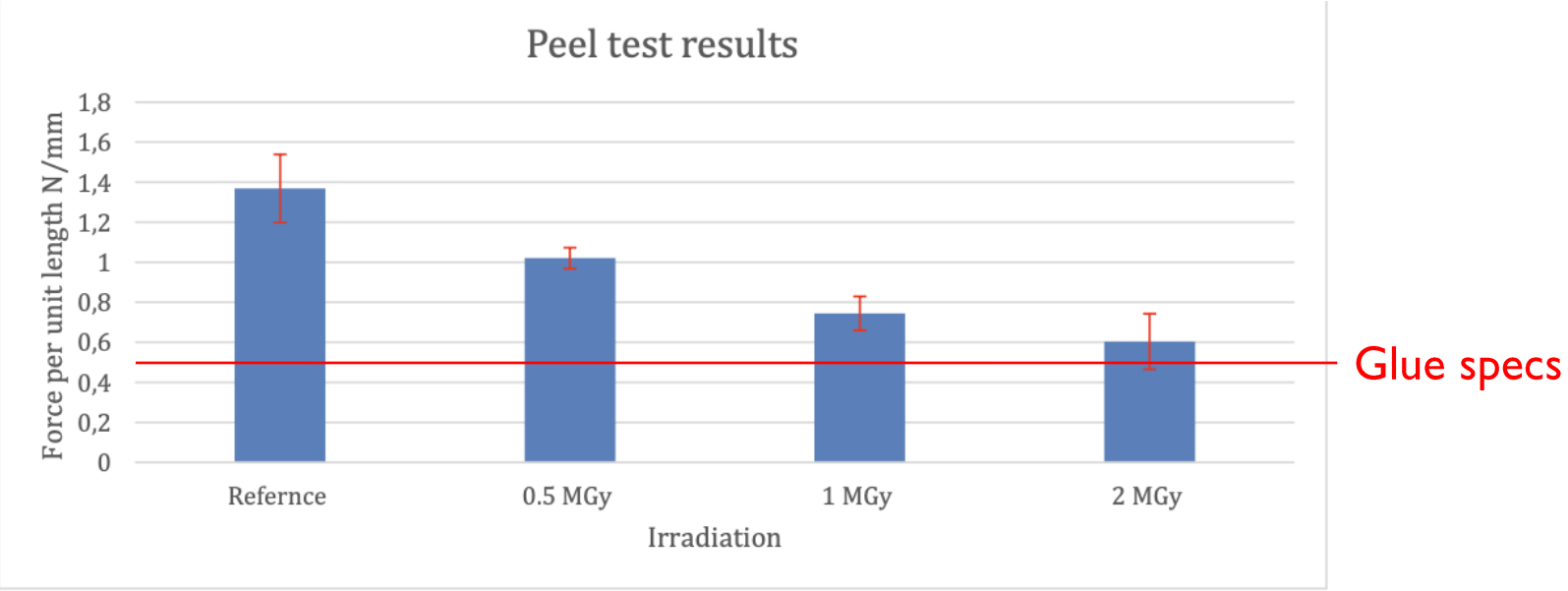
- 2nd round irradiation test
  - 2024.05 @KIT.
  - Integrated dose: 2 MGy.
  - Sample: new version IHEP baseplates(2 layers of same version glue).
  - Humidity control: done.
  - Heat-treated for 5 min at 170-180 °C.
  - No delamination observed, only small defect appeared after heat treatment.

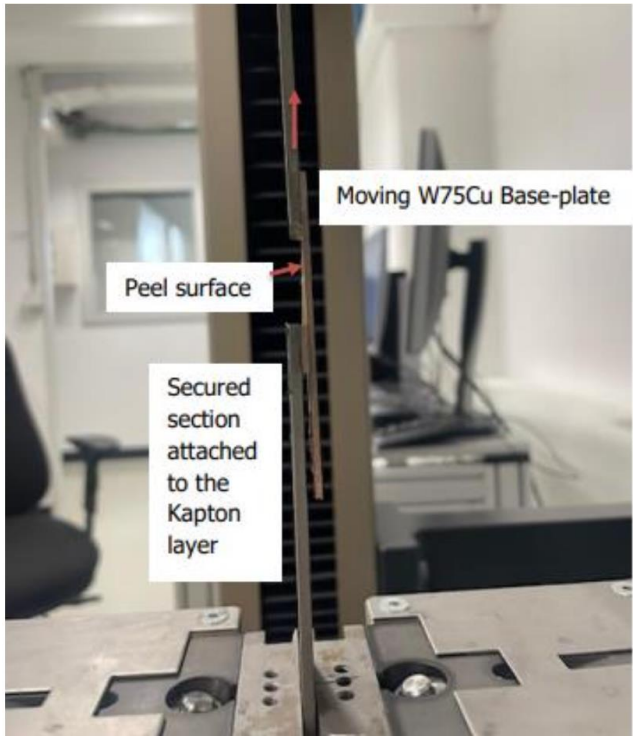
- 3rd round irradiation test
  - 2024.09 @CIEMAT.
  - Integrated dose: 0.5 MGy, 1 MGy, 1~2 MGy.
  - Sample: new version IHEP baseplates(2 layers of same version glue).
  - Humidity control: done.
  - No delamination observed.



Peel test

- Motivation: evaluate whether irradiation caused significant degradation to adhesive.
- Using mechanical testing machine, test adhesive performance of 2nd layer glue.
- Sample: unirradiated reference sample, irradiated by 0.5 MGy, 1 MGy, 2 MGy samples.
- Results: samples showed a steady decline in peel strength with the increase in accumulated doses. 2 MGy sample showed significant peeling after test.
- Although irradiation can affect peel strength, the test results meet the requirements(glue specifications: < 0.5 N/mm when irradiation dose = 2 MGy).

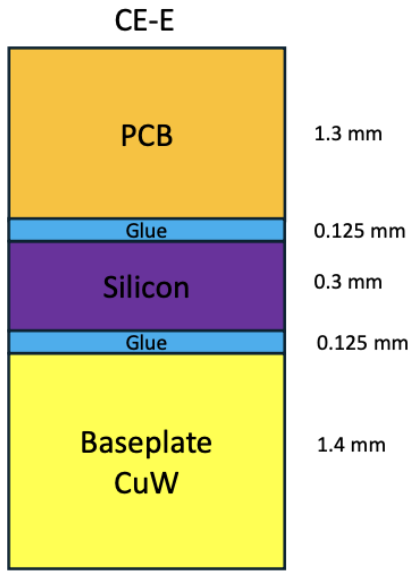




Mechanics study

- Conducted by CERN
- Motivation: when module cool down from room temperature to -35 $^{\circ}C$, stress is generated in Silicon sensor.
- Silicon Yield stress ~ 350 MPa, CuW baseplate's Si max stress is 84 MPa, so it's safety in simulation.
- In the temperature cycling tests conducted by NTU and KIT so far, no module damage has been found.

Complete module:



Material properties:

	Young's Modulus (Gpa)	CTE ($°C^{-1}$)x10^{-6}
Araldite 2011	0.91	85
CF	70	3
Silicon	130	2.6
PCB	29	16
CuW	260	9

Simulation results:

	CF	Alumina	CuW (1.4 mm)	Titanium	PCB
Si Max Stresses (MPa)	139	94	84	91	115
Module Max. vertical def. (mm)	0.126	0.070	0.018	0.047	0.024

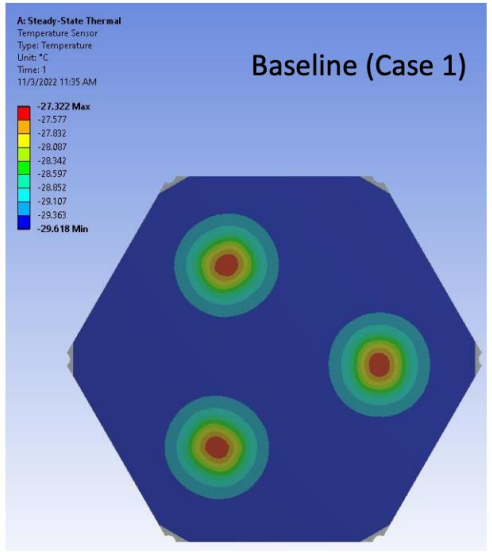
Heat flow study

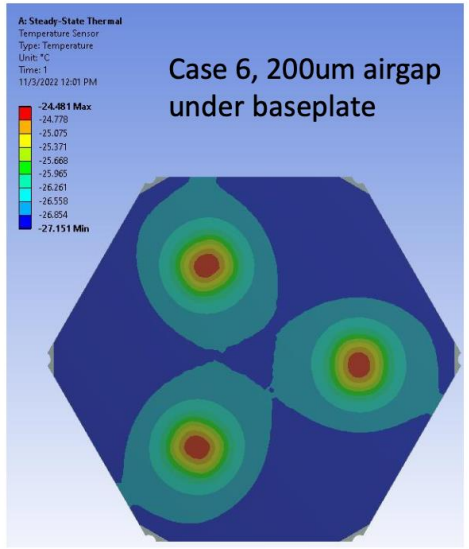
- Conducted by UCSB
- Steady state thermal simulation of heat flow through the module.
- Determine sensor temperature and temperature gradient, using different airgaps and materials.
- Better flatness, smaller airgap, temperature distribution is more uniform.
- All cases' max/min temperature and temperature gradient performed well. It will not cause damage to the Silicon sensor.

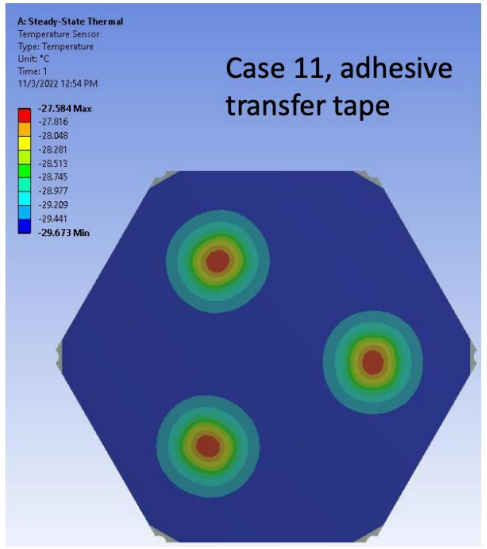
CE-E Results

LD Module CE-E	Baseline Case 1 CuW BP	Case 2 W BP	Case 3 Cu BP	Case 4 CuW BP, .05mm airgap	Case 5 CuW BP, .1mm airgap	Case 6 CuW BP, .2mm airgap	Case 7 CuW BP, .25mm Hexaboard adhesive	Case 8 CuW BP, .05mm sensor adhesive	Case 9 CuW BP, .1mm kapton	Case 10 CuW BP, .017mm copper	Case 11 Case 7 & Case 8	Case 14 CuW BP airgap 0-300
max. module temperature [°C]	-12.21	-12.21	-12.21	-12.01	-11.11	-9.26	-10.65	-12.86	-12.2	-11.95	-9.87	-10.21
max. sensor temp [°C]	-27.32	-27.32	-27.32	-26.5	-25.84	-24.48	-27.34	-27.56	-26.69	-27.3	-27.58	-26.01
min. sensor temp [°C]	-29.62	-29.62	-29.62	-29.08	-28.45	-27.15	-29.62	-29.67	-29.44	-29.62	-29.67	-29.52
ΔT on sensor [°C]	2.3	2.3	2.3	2.58	2.61	2.67	2.28	2.11	2.75	2.32	2.09	3.51

CE-E Results: Temperature distribution on Sensor

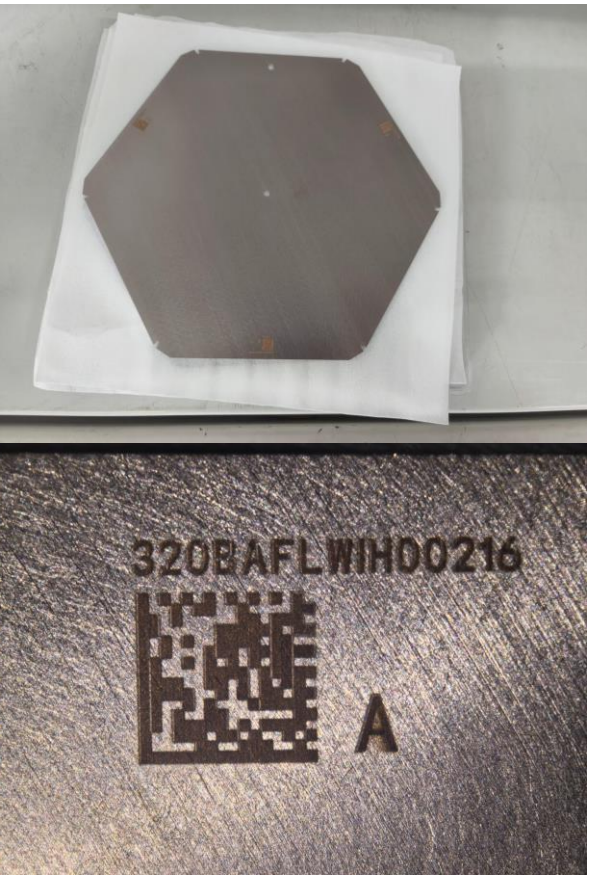


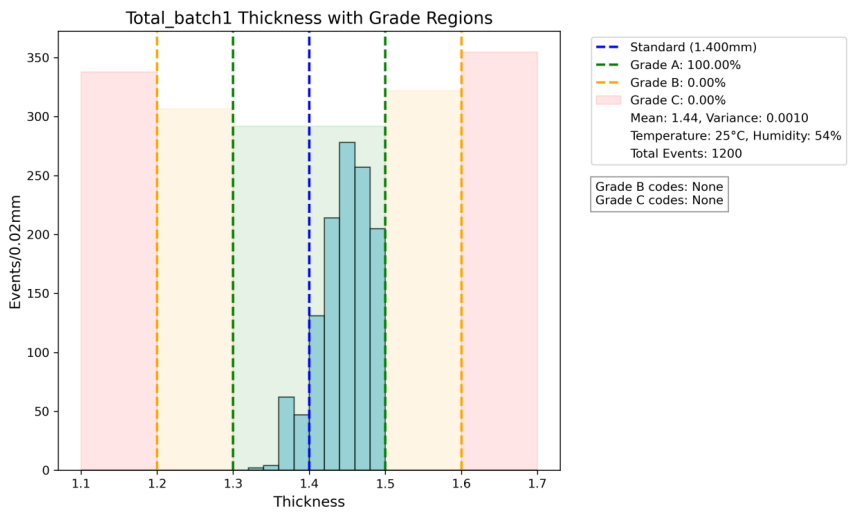


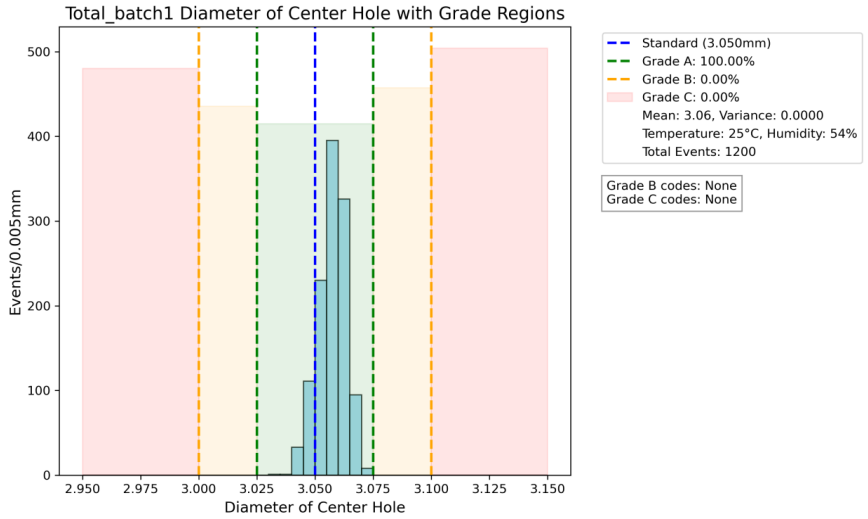


CuW baseplate specification inspection

- CuW baseplate company measured all specifications in CuW baseplate design, for all 1200 pre-batch baseplates. (Also measured all extra 100 baseplates for KIT)
- All 1200+100 CuW baseplates passed Grade A.
- All specifications are tested by Vision Measuring Machine, accuracy ~ 0.002mm.
- QR code print is just before the measure process, so surface A/B are random. We always measure surface A.



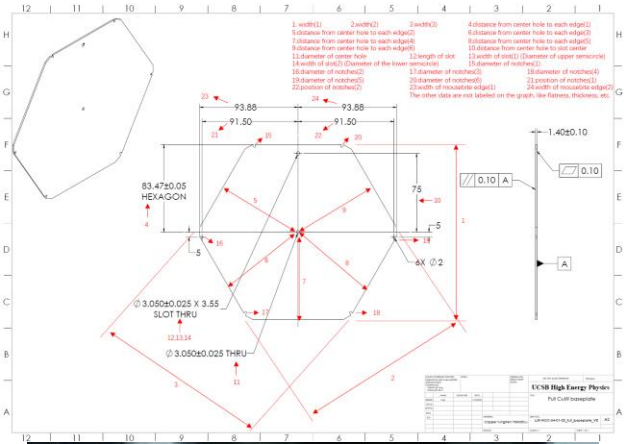


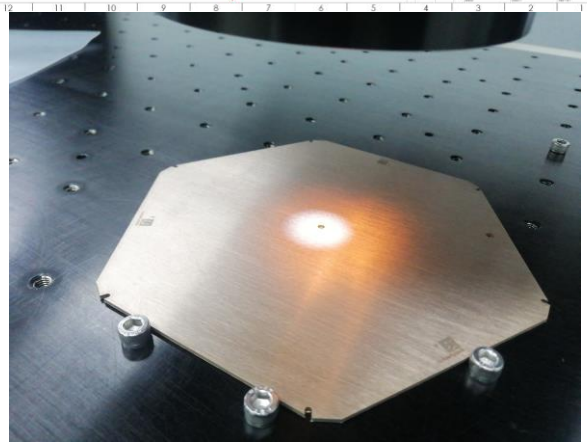


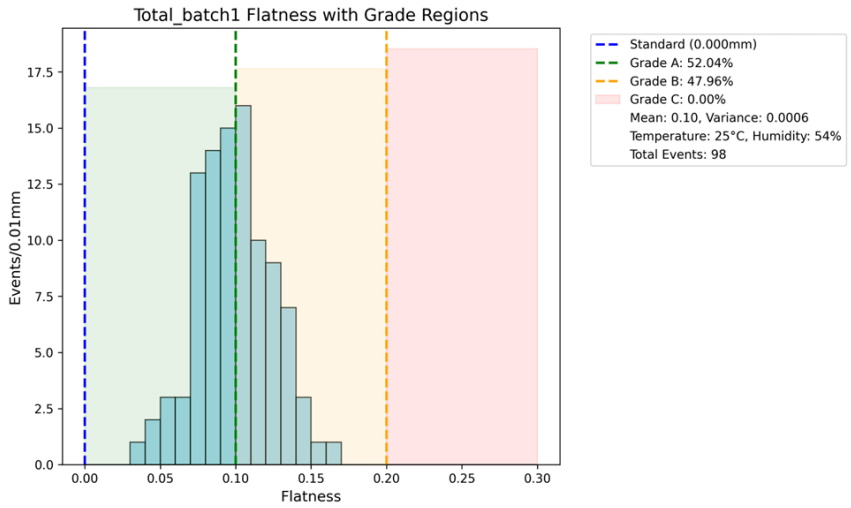
Thickness and diameter of center hole distribution.
Other specification details in backup.

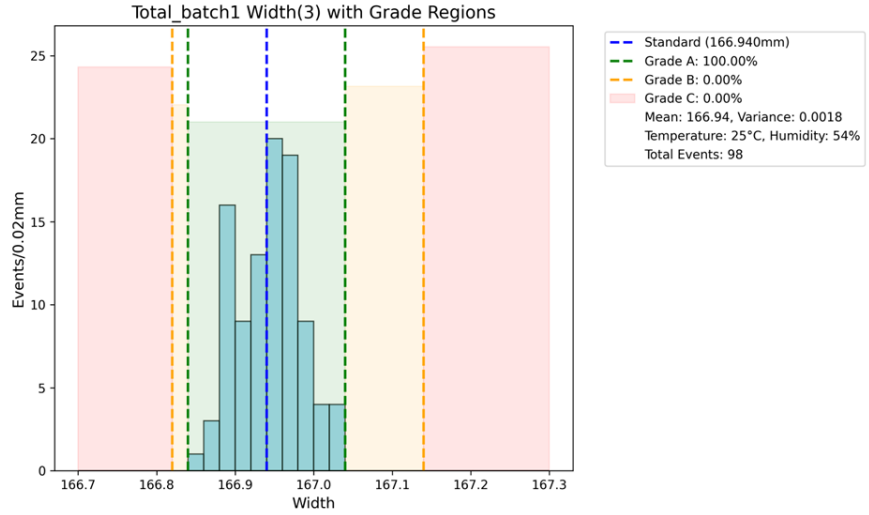
CuW baseplate spot check

- Random select 98 CuW baseplates from all 1200 pre-batch baseplates sent to IHEP.
- Measured specifications in CuW baseplate using OGP as cross-check to CuW baseplate company's result.
- Result shows most specification can still reach a high Grade A percentage compare to baseplate factory result*(degradation mainly due to lamination process, plan to fix next)







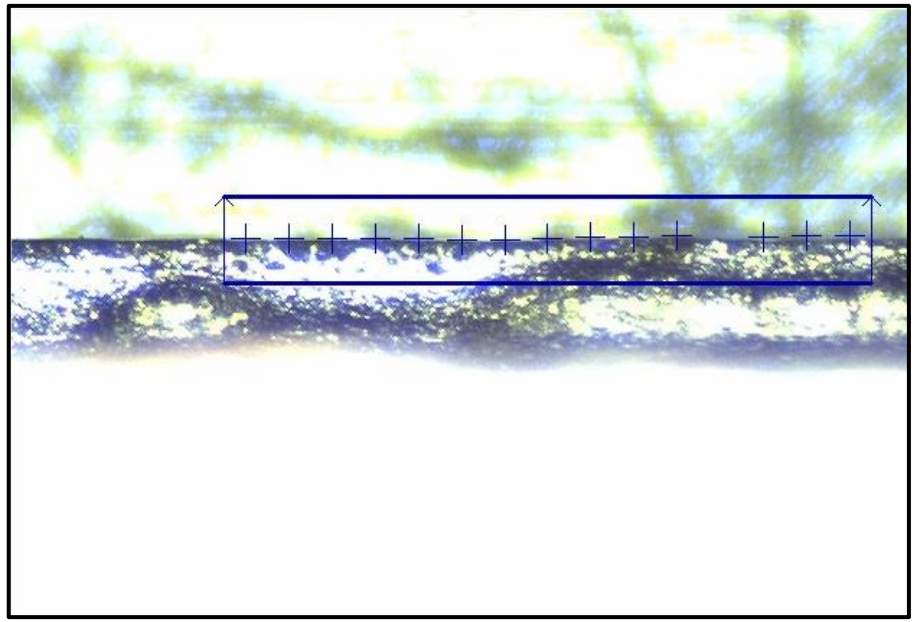


Flatness and distance from center to edge distribution.
Other specification details in backup.

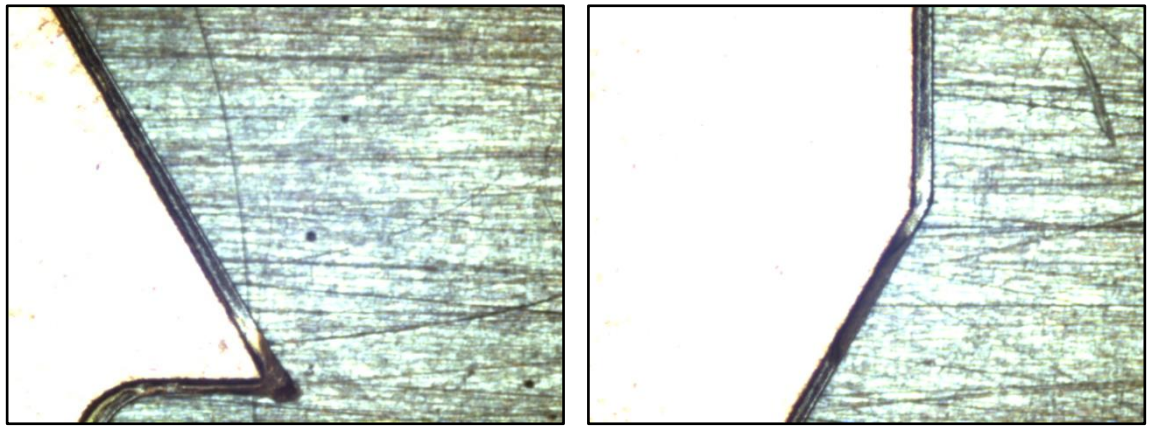
*Detail are listed in backup, PPT page31

CuW baseplate kapton boundary check

- Exam the Kapton boundary by locate the position and record pictures at two end points
- For all 98 baseplates, none of CuW baseplate edge exceed the Kapton boundary and mostly are well aligned



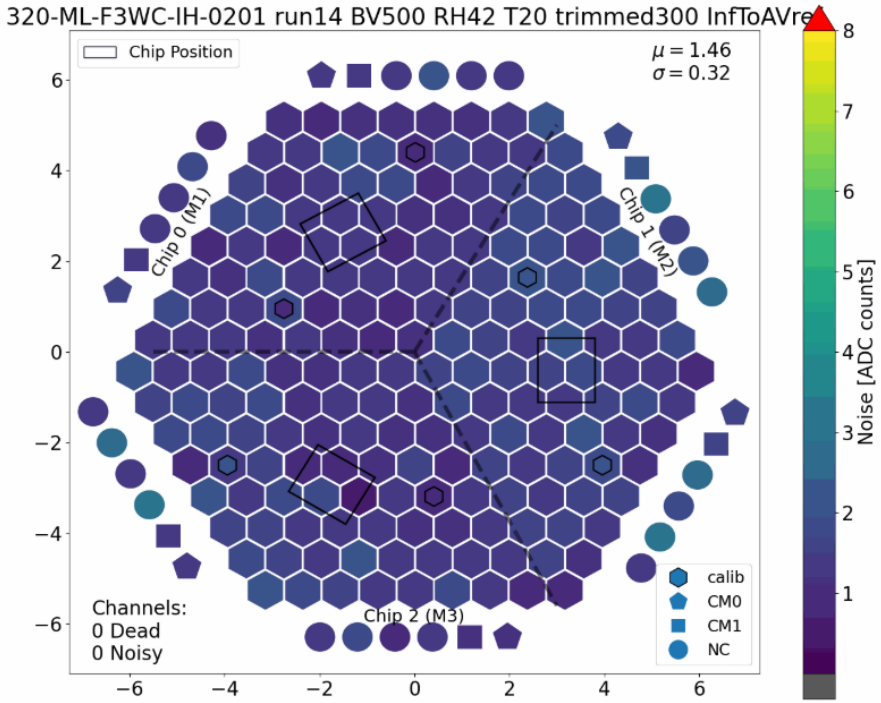
measurement pictures to locate the kapton boundary



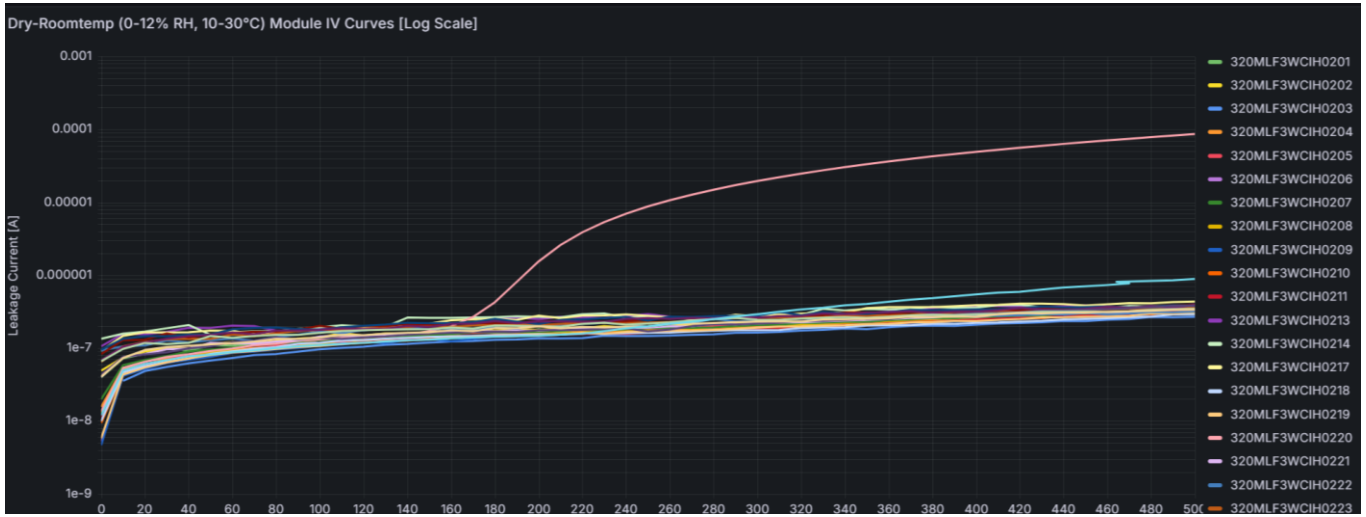
Exam pictures for end point of kapton boundary

New modules performace with new baseplate

- For now 28 modules has assembled with new IHEP produced CuW baseplates
- Electronics test shows all completed modules meet the standard as good noise and good IV



noise channel result for one baseplate,
good noise require noisy+dead+unbound channels ≤ 4



I-V result for all 28 modules, good IV require I_{500V}<100μA

Future production plan

Production plan & contract status

Production plan:

- Pre-batch 1200 bare CuW ready and tested/labeled at July 2025, next batch 2500 bare CuW have just done manufacture, and for shipment:
  - 200LD plan to ship to CMU
  - 200LD plan to ship to TTU
  - 199HD plan to ship to NTU&UCSB
  - 100LD ship to TIFR
  - 468LD for IHEP pre-prodution
- Extra 100 bare CuW for KIT now at IHEP.
  - Have sent to CERN.

Contract status:

- CERN's K-contract: CERN's K-contract has been signed, November 2024.
- Industrial production contract:
  - The production contract with CuW baseplate factory signed at February 2025, and contract with Kapton factory signed at May 2025

Future Plan

Nov. 2025	Mar. 2026	Jun. 2026	Sept. 2026	Dec. 2026
2500 (1500LD +1000HD)	2500	2500	1300	2500

Summary

Summary

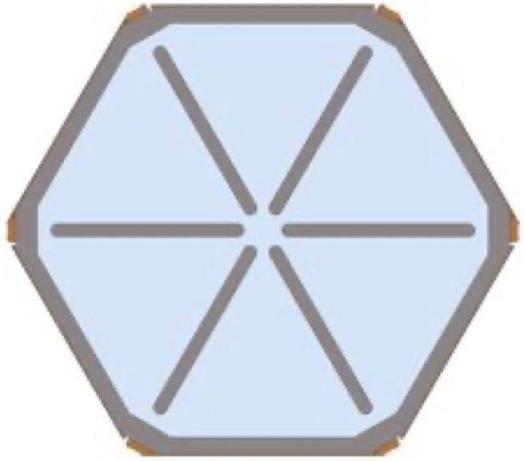
- CuW baseplate introduction & production status:
  - 2 Kapton assembly process : IHEP, KIT.
  - So far, IHEP has produced the most CuW baseplates used for module assembly and testing.
- Irradiation test, Mechanics study, Heat flow study, peel test & specs inspection:
  - Irradiation test: No delamination observed.
  - Peel test: test results satisfy our requirements.
  - Mechanics study: Silicon Yield stress ~ 350 MPa CuW baseplate's Si max stress is 84 MPa , it's safety for Silicon sensor.
  - Heat flow study: Heat flow and temperature gradient perform well, it will not cause damage to the Silicon sensor.
  - IHEP CuW baseplates have passed all tests so far.
  - Specification inspection: all 1300 IHEP CuW baseplates specifications passed Grade A.
  - Spot check shows most specification can still reach a high Grade A percentage
- Future production plan:
  - IHEP will produce most of CuW baseplates(~90%).
  - CERN's K-contract signed, the production contract with CuW baseplate factory and Kapton factory have signed too

Thanks

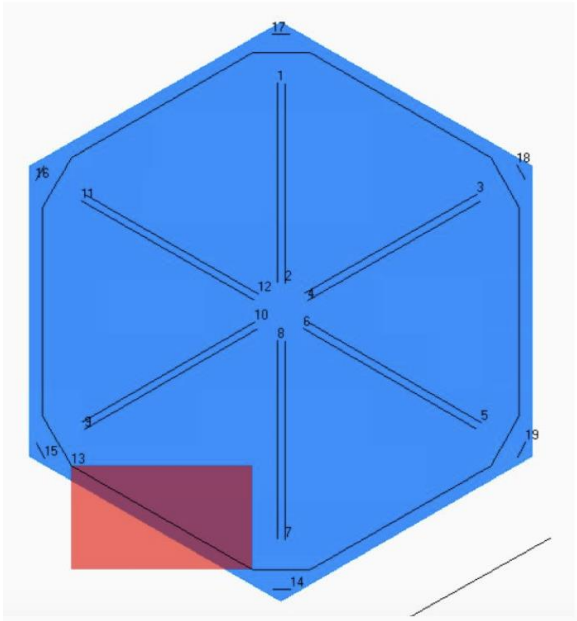
Backup

CuW Baseplate production status

KIT Kapton assembly process:



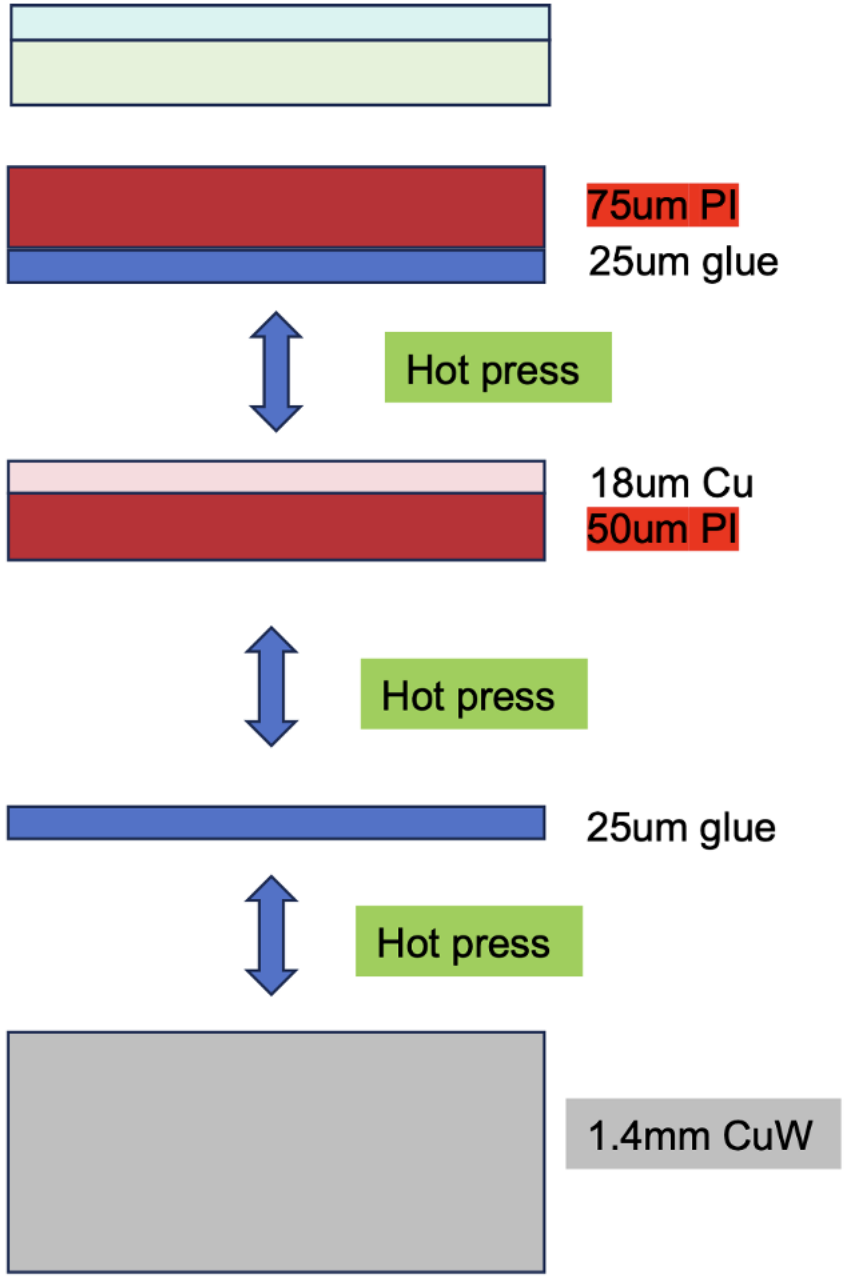
- Hybrid attachment with 3M F9460PC tape (top image, blue area) and Araldite 2011 epoxy (grey).
- Using PreciFluid volumetric glue dispenser and our Tracker lab's 3-axis gantry.
- Glue application pattern consists of 2 lines of glue in each cutout, dodecagon following the shape of the tape, and a line in each corner.
- After lamination, put in book press overnight to cure.



CuW Baseplate production status

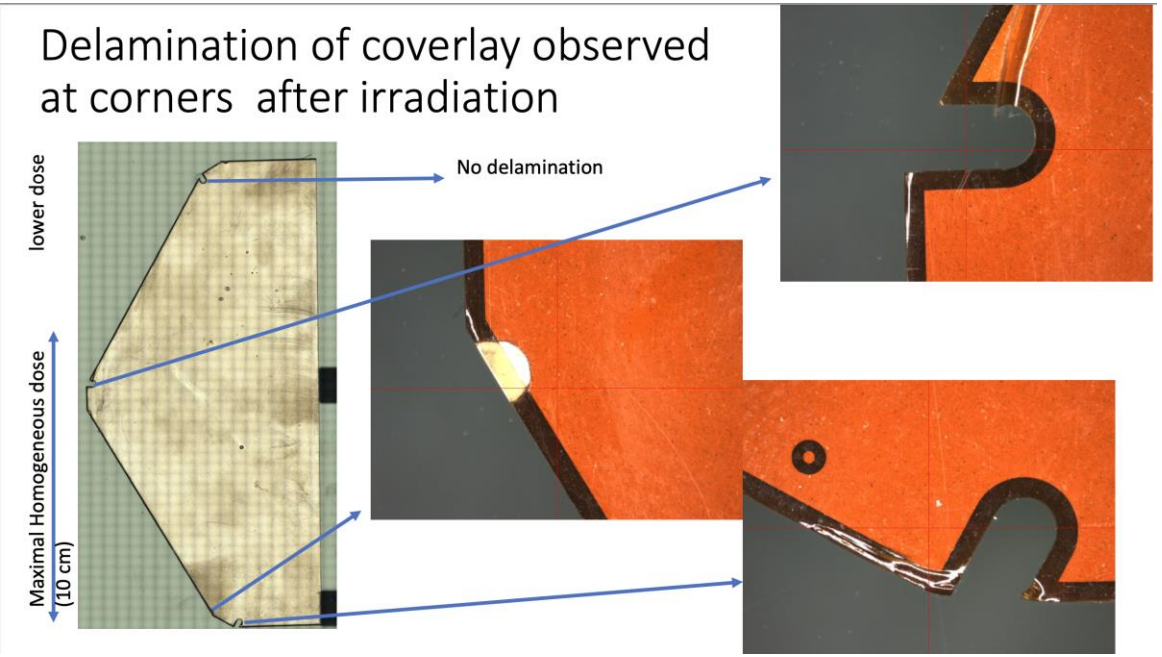
IHEP Kapton assembly process :

- Optional: 50 um 3M transfertape + protection paper for hybrid sensor gluing.
- Coverlay: Taihong MHK3025 (100um= 75um PI + 25um glue), made of a polyimide film, one side or both sides of which is coated with a prescribed adhesive and then overlaid with polyimide film.
- Bottom layer: Panasonic R-F777 (18 um Cu+50 um PI).
- Pure adhesive: HaynerTaiXing Electronics HC25 (25um), epoxy adhesive, melts when heated.
- Kapton and CuW are bonded together through a hot pressing process at a temperature of approximately 180°C.



Irradiation test

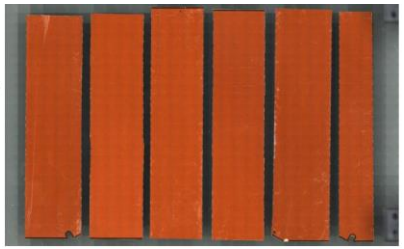
- Irradiation test @CIEMAT: May 2024 and Sept 2024



- 1st test in May. 2024:
- 2 MGy over 10 days and 15 h, ~ 8 kGy/h
- Integrated dose is homogeneous in the bottom 10 cm of the plate, gradually decreases
- Due to High humidity (80/90 %), delamination of coverlay observed

1. 50% of the samples have been irradiated to 0.5 MGy (no delamination with visual evaluation)
2. 50% of the samples are being irradiated to 1 MGy
3. 25% of the samples will be irradiated from 1 MGy to 2MGy

Device: 21.24 KGy/h. (Samples were placed along the walls of the device so that all receive a uniform dose)



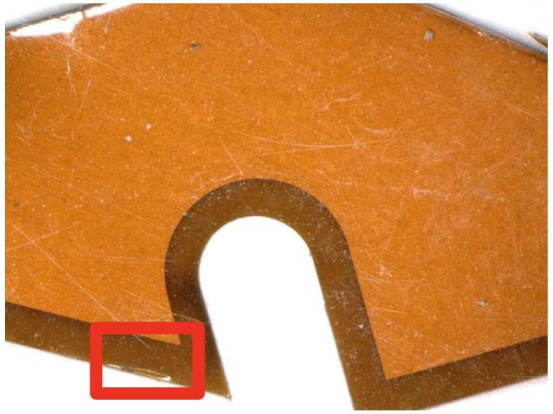
- 2nd test in Sept. 2024:
- Humidity control: done
- Irradiated to 0.5MGy,1MGy, 1~2MGy
- No delamination observed
- Peel test will be done @CERN

Irradiation test

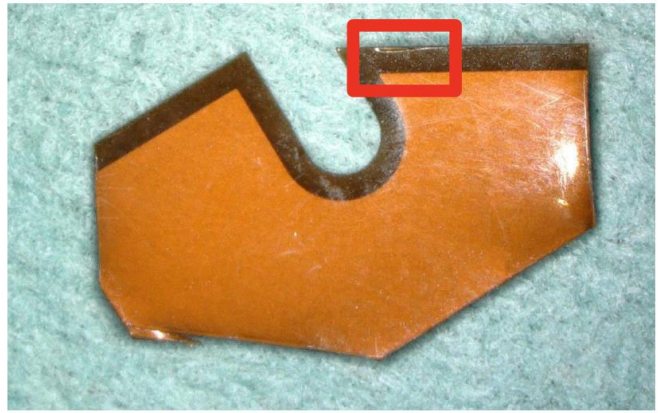
- Irradiation test @KIT: May. 2024
- Irradiation of heat-treated "IHEP" type Kapton to 2 MGy after 5 minutes at 170 - 180 °C
- No delamination observed
- Only small defect appeared after heat treatment

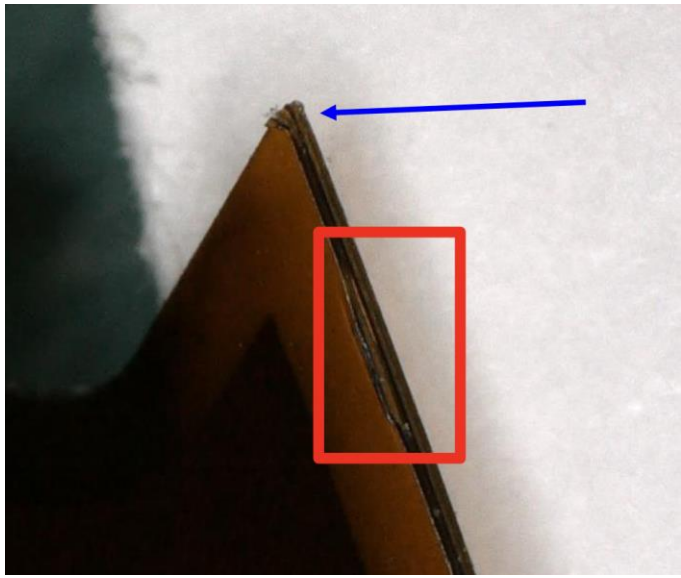
Before

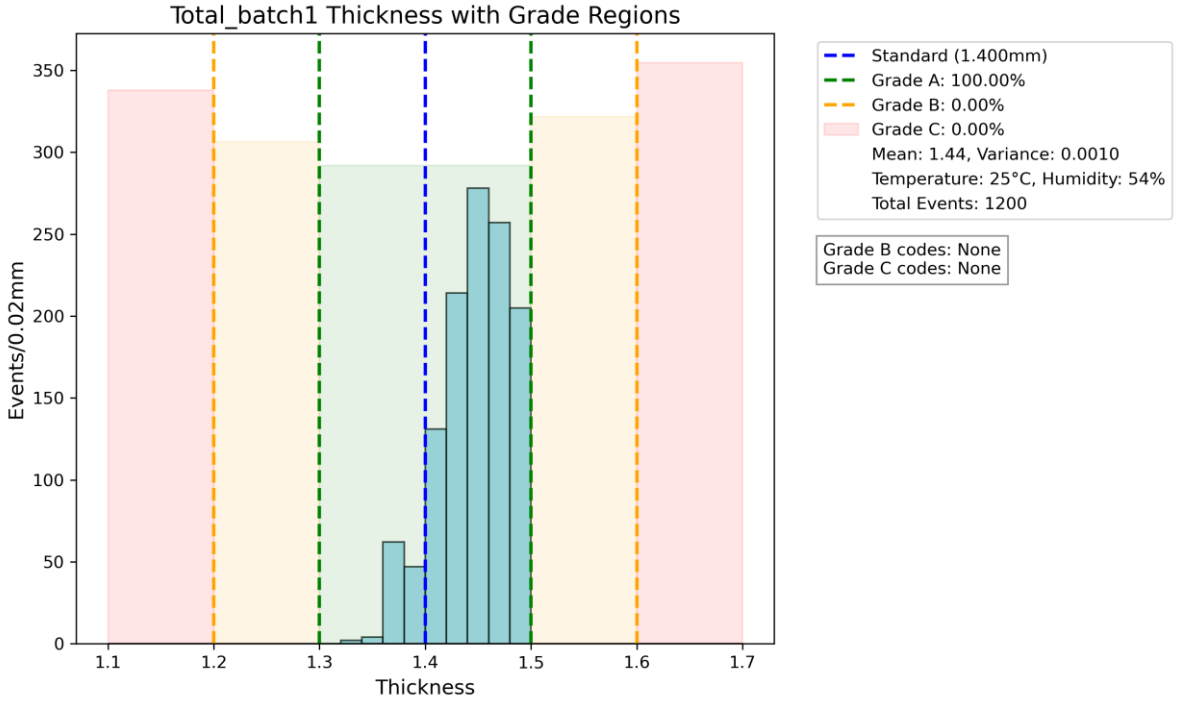
After heat-treatment

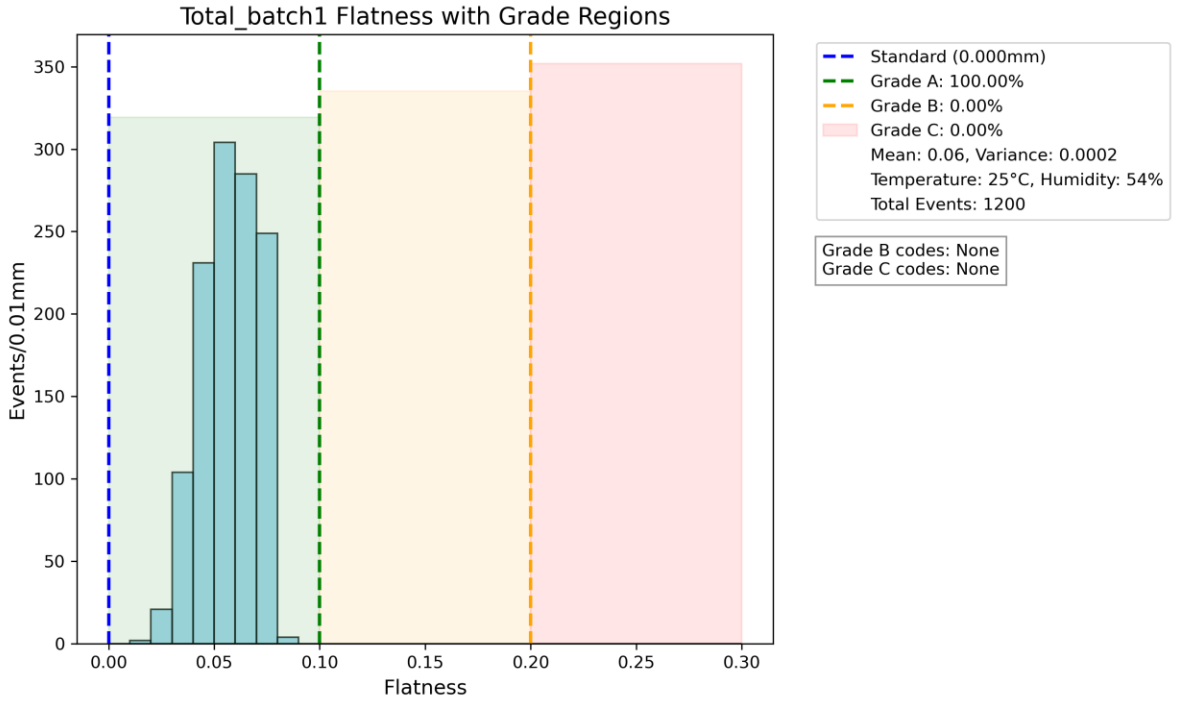


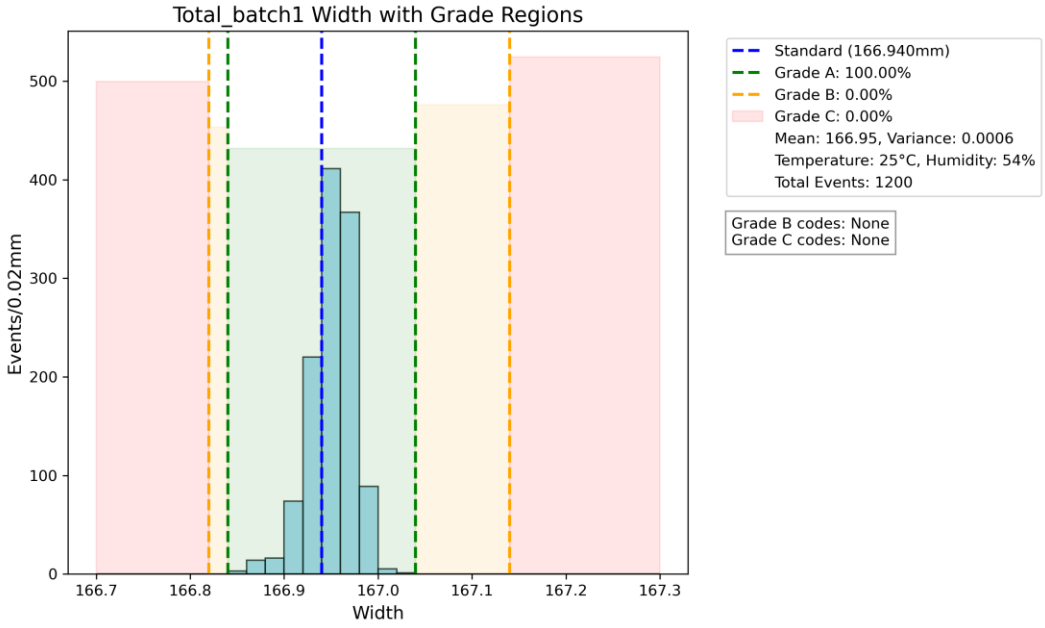
After irradiation

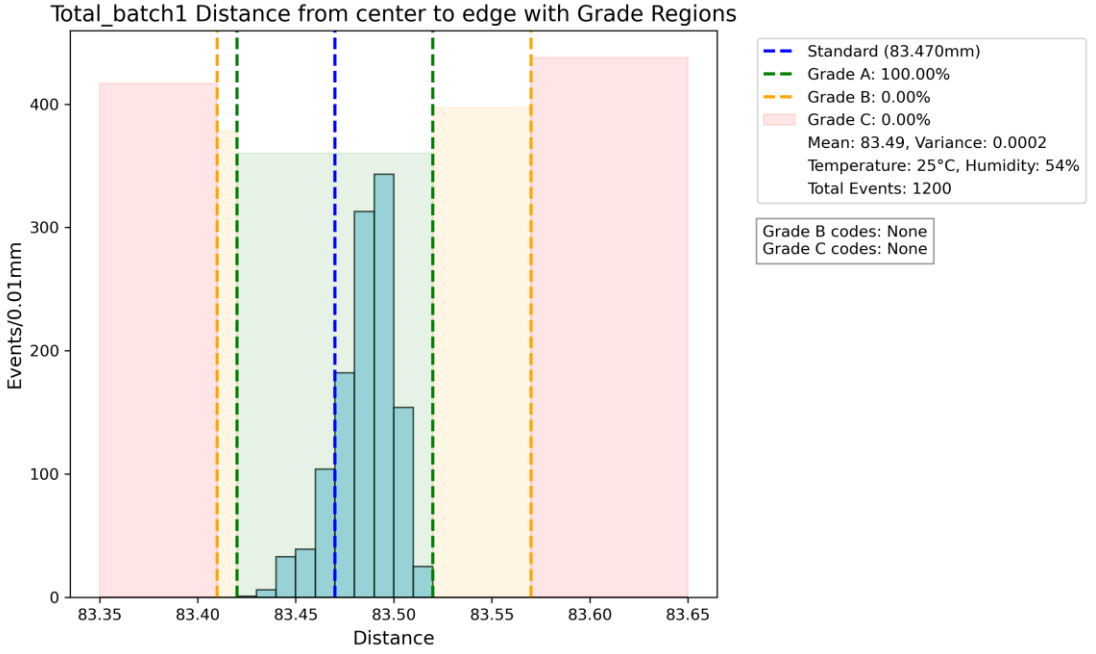


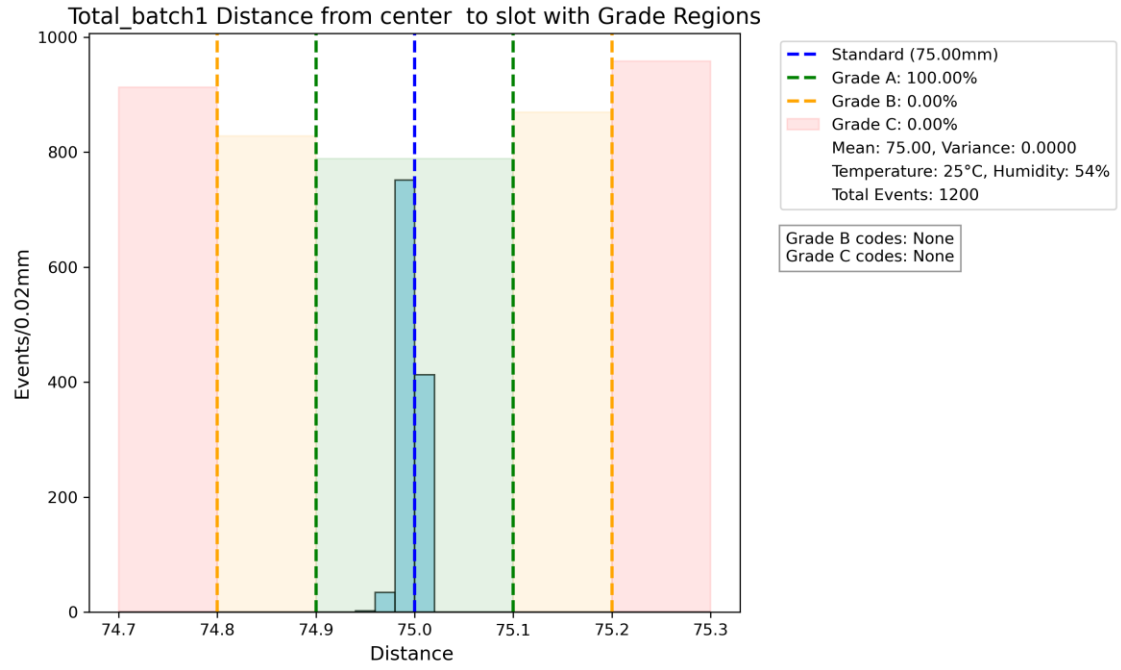


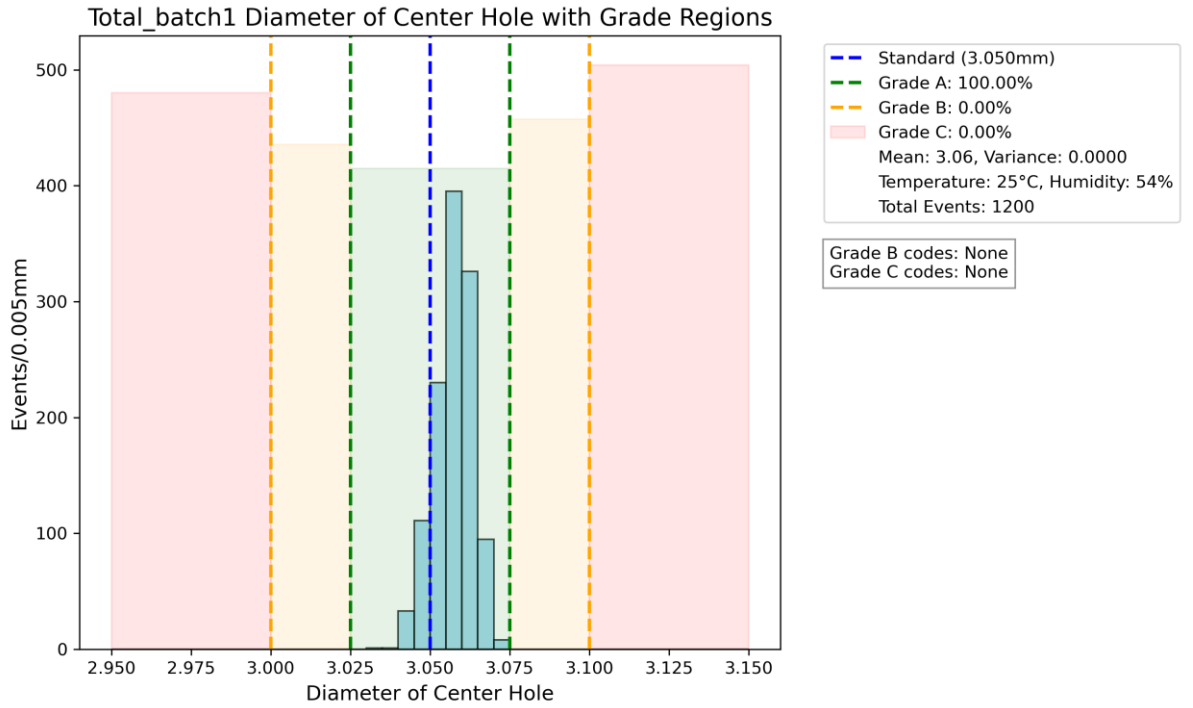

Total_batch1 Thickness with Grade Regions
Standard (1.400mm)
Grade A: 100.00%
Grade B: 0.00%
Grade C: 0.00%
Mean: 1.44, Variance: 0.0010
Temperature: 25°C, Humidity: 54%
Total Events: 1200
Grade B codes: None
Grade C codes: None
Events/0.02mm
Thickness

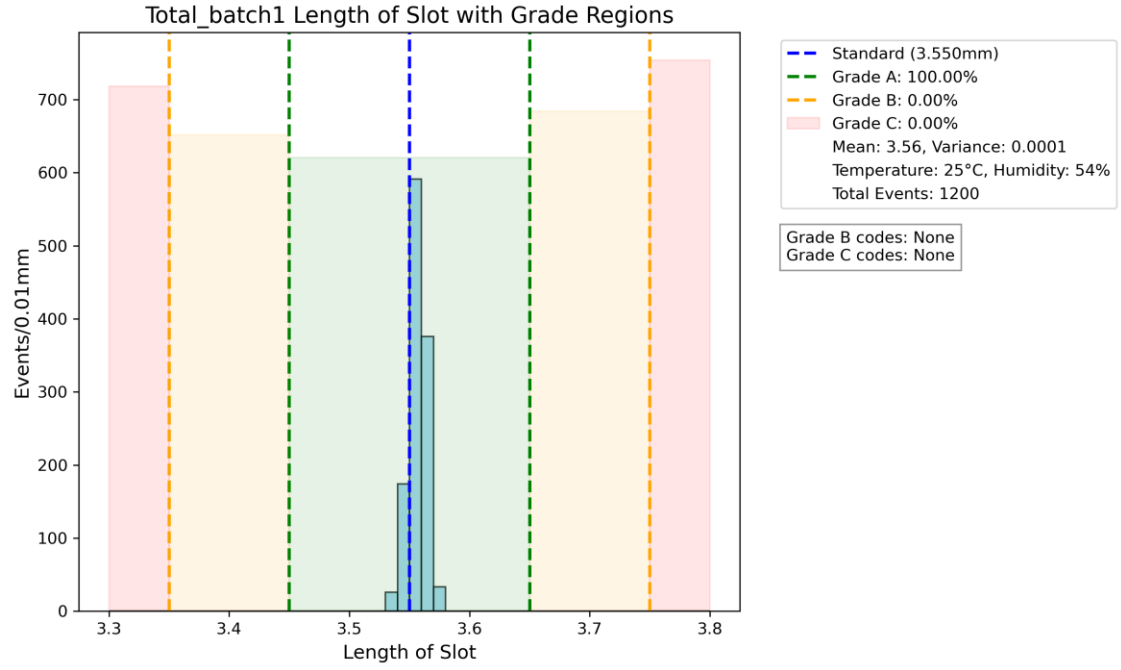

Total_batch1 Flatness with Grade Regions
Standard (0.000mm)
Grade A: 100.00%
Grade B: 0.00%
Grade C: 0.00%
Mean: 0.06, Variance: 0.0002
Temperature: 25°C, Humidity: 54%
Total Events: 1200
Grade B codes: None
Grade C codes: None
Events/0.01mm
Flatness

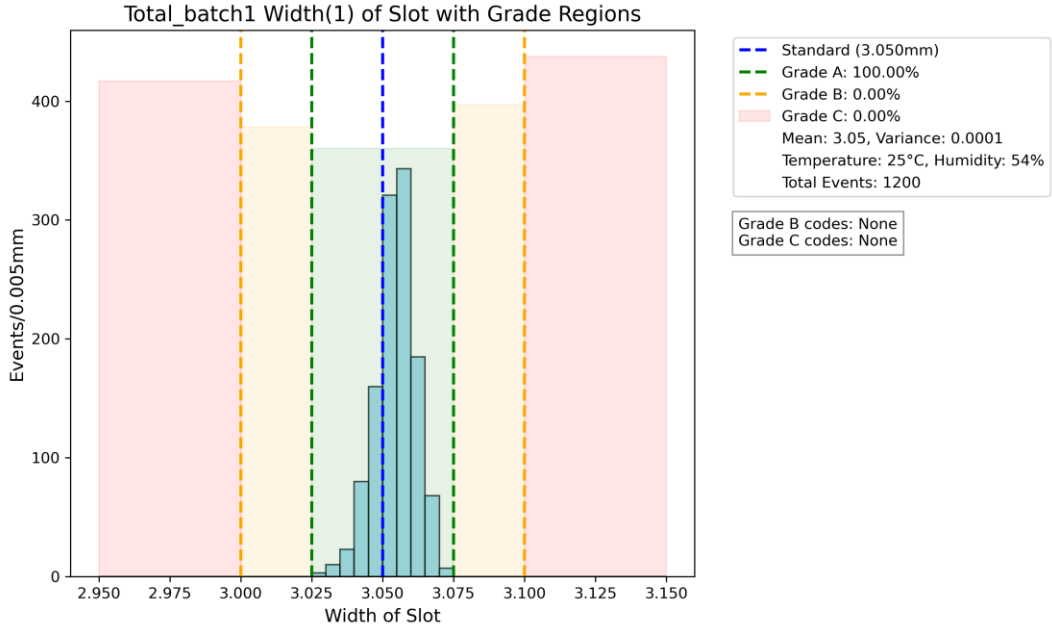

Total_batch1 Width with Grade Regions
Standard (166.940mm)
Grade A: 100.00%
Grade B: 0.00%
Grade C: 0.00%
Mean: 166.95, Variance: 0.0006
Temperature: 25°C, Humidity: 54%
Total Events: 1200
Grade B codes: None
Grade C codes: None
Events/0.02mm
Width

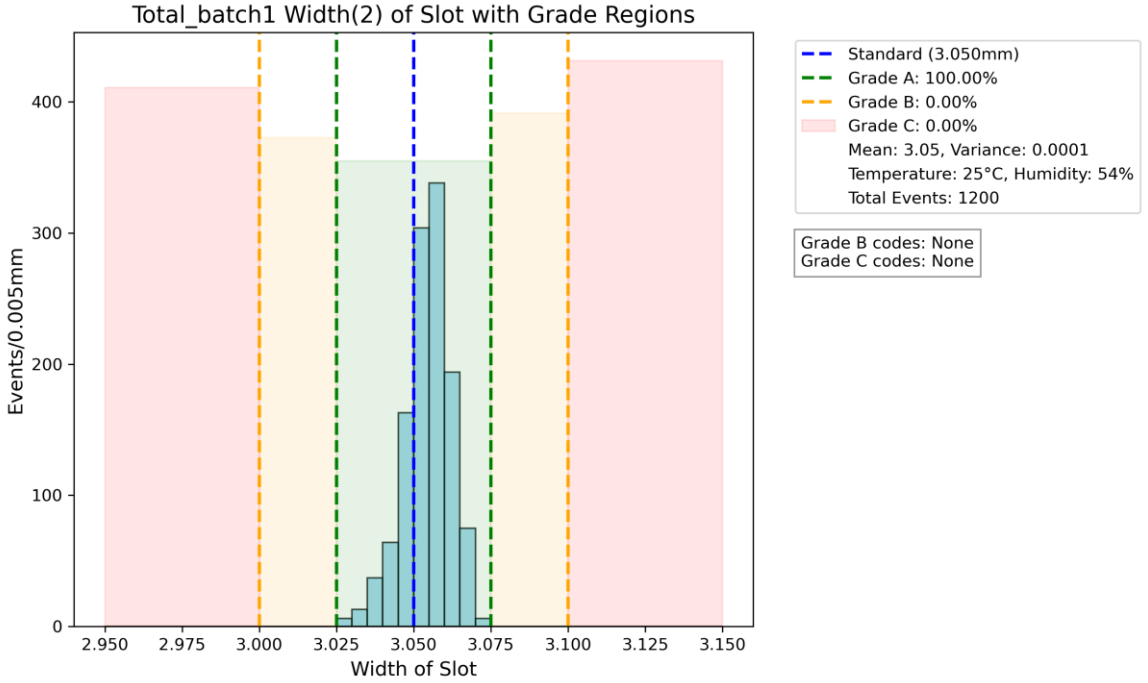

Total_batch1 Distance from center to edge with Grade Regions
Standard (83.470mm)
Grade A: 100.00%
Grade B: 0.00%
Grade C: 0.00%
Mean: 83.49, Variance: 0.0002
Temperature: 25°C, Humidity: 54%
Total Events: 1200
Grade B codes: None
Grade C codes: None
Events/0.01mm
Distance

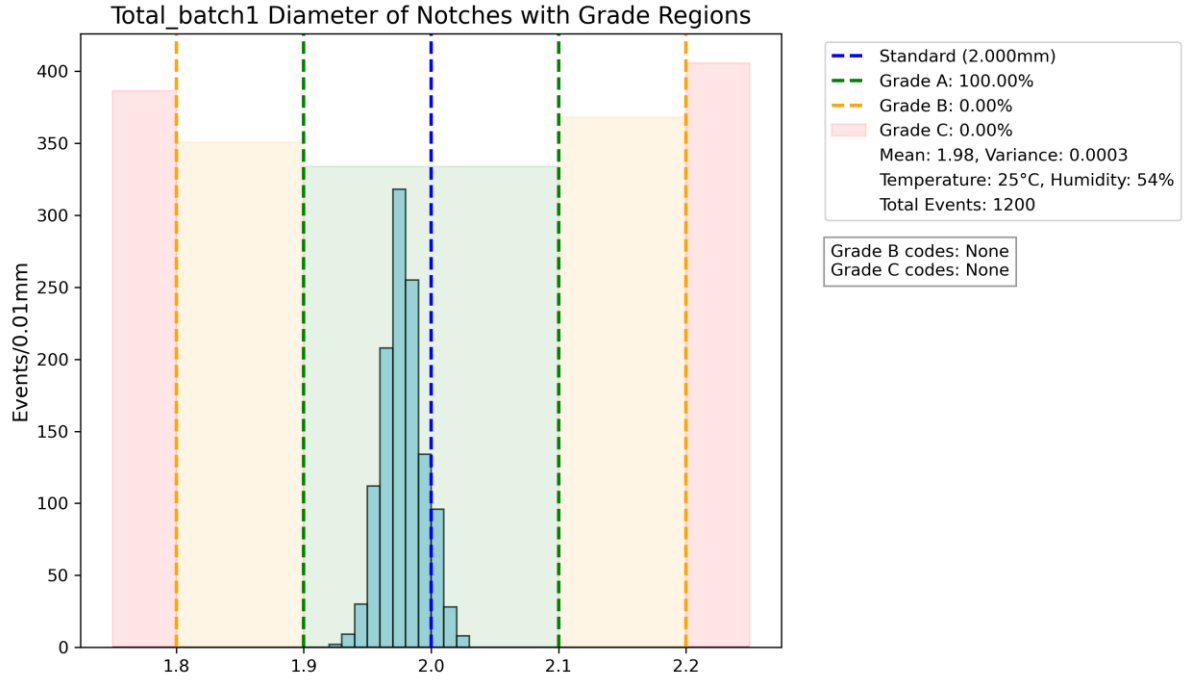

Total_batch1 Distance from center to slot with Grade Regions
Standard (75.00mm)
Grade A: 100.00%
Grade B: 0.00%
Grade C: 0.00%
Mean: 75.00, Variance: 0.0000
Temperature: 25°C, Humidity: 54%
Total Events: 1200
Grade B codes: None
Grade C codes: None
Events/0.02mm
Distance

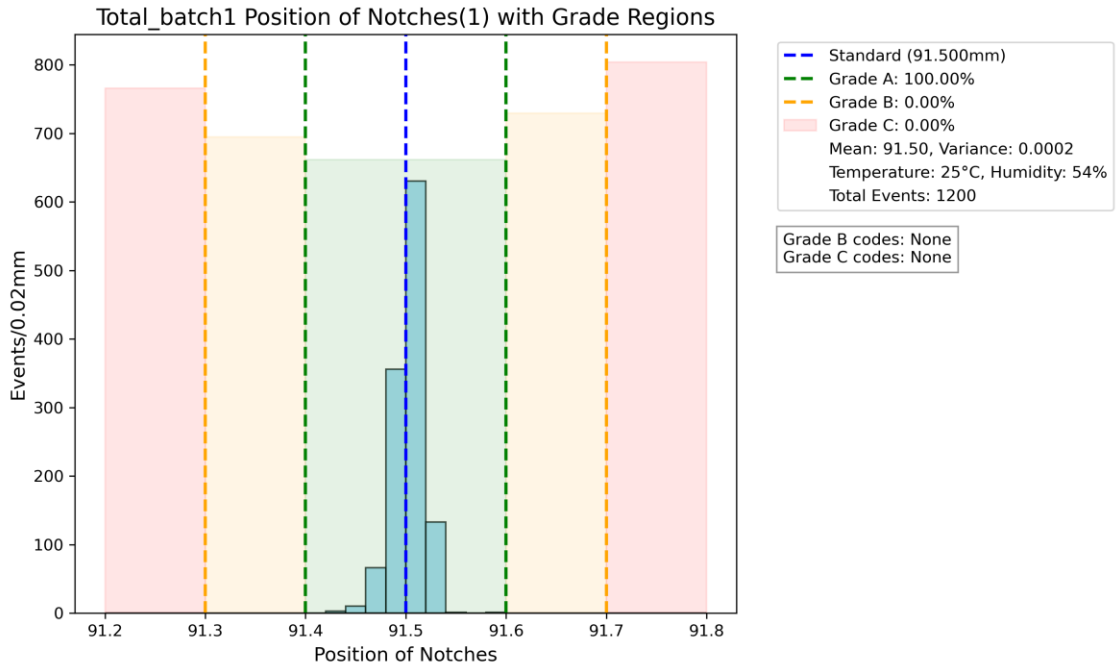

Total_batch1 Diameter of Center Hole with Grade Regions
Standard (3.050mm)
Grade A: 100.00%
Grade B: 0.00%
Grade C: 0.00%
Mean: 3.06, Variance: 0.0000
Temperature: 25°C, Humidity: 54%
Total Events: 1200
Grade B codes: None
Grade C codes: None
Events/0.005mm
Diameter of Center Hole

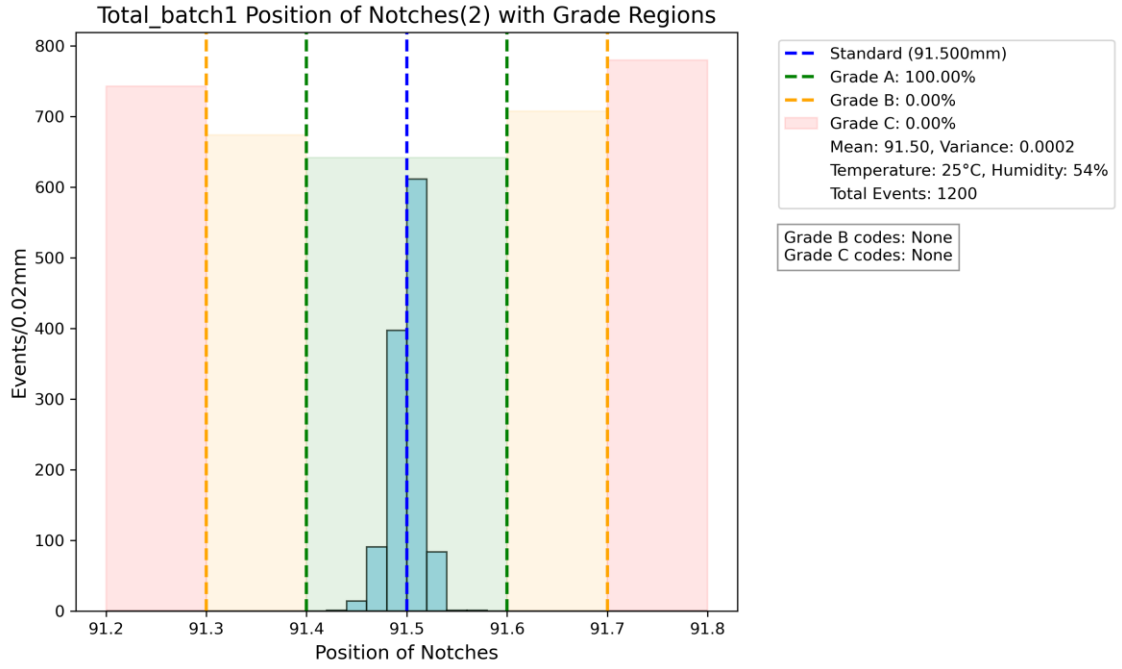

Total_batch1 Length of Slot with Grade Regions
Standard (3.550mm)
Grade A: 100.00%
Grade B: 0.00%
Grade C: 0.00%
Mean: 3.56, Variance: 0.0001
Temperature: 25°C, Humidity: 54%
Total Events: 1200
Grade B codes: None
Grade C codes: None
Events/0.01mm
Length of Slot

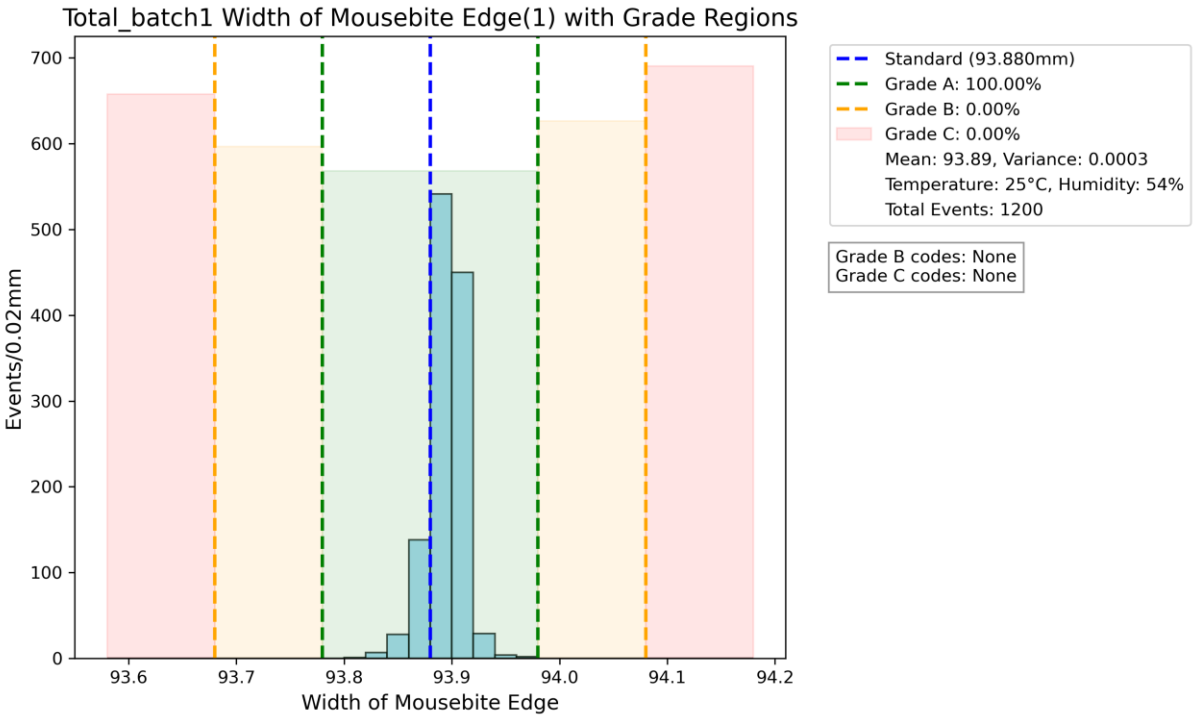

Total_batch1 Width(1) of Slot with Grade Regions
Standard (3.050mm)
Grade A: 100.00%
Grade B: 0.00%
Grade C: 0.00%
Mean: 3.05, Variance: 0.0001
Temperature: 25°C, Humidity: 54%
Total Events: 1200
Grade B codes: None
Grade C codes: None
Events/0.005mm
Width of Slot

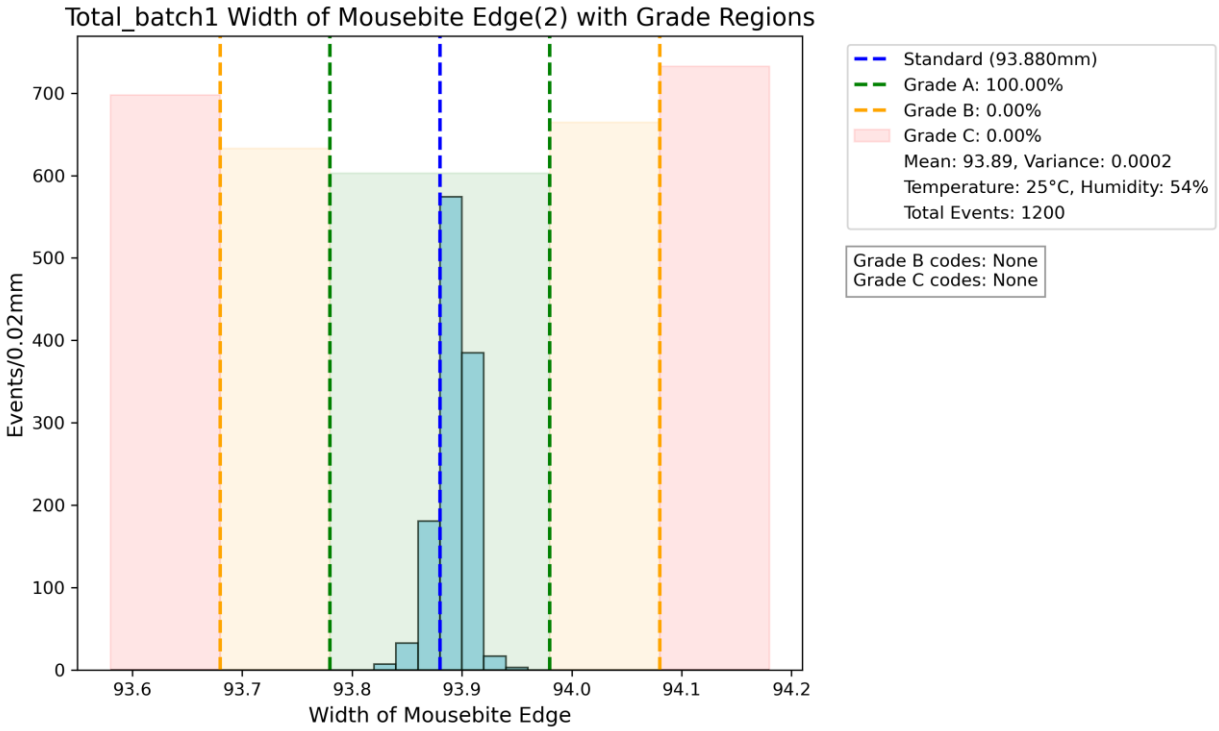

Total_batch1 Width(2) of Slot with Grade Regions
Standard (3.050mm)
Grade A: 100.00%
Grade B: 0.00%
Grade C: 0.00%
Mean: 3.05, Variance: 0.0001
Temperature: 25°C, Humidity: 54%
Total Events: 1200
Grade B codes: None
Grade C codes: None
Events/0.005mm
Width of Slot


Total_batch1 Diameter of Notches with Grade Regions
Standard (2.000mm)
Grade A: 100.00%
Grade B: 0.00%
Grade C: 0.00%
Mean: 1.98, Variance: 0.0003
Temperature: 25°C, Humidity: 54%
Total Events: 1200
Grade B codes: None
Grade C codes: None
Events/0.01mm


Total_batch1 Position of Notches(1) with Grade Regions
Standard (91.500mm)
Grade A: 100.00%
Grade B: 0.00%
Grade C: 0.00%
Mean: 91.50, Variance: 0.0002
Temperature: 25°C, Humidity: 54%
Total Events: 1200
Grade B codes: None
Grade C codes: None
Events/0.02mm
Position of Notches

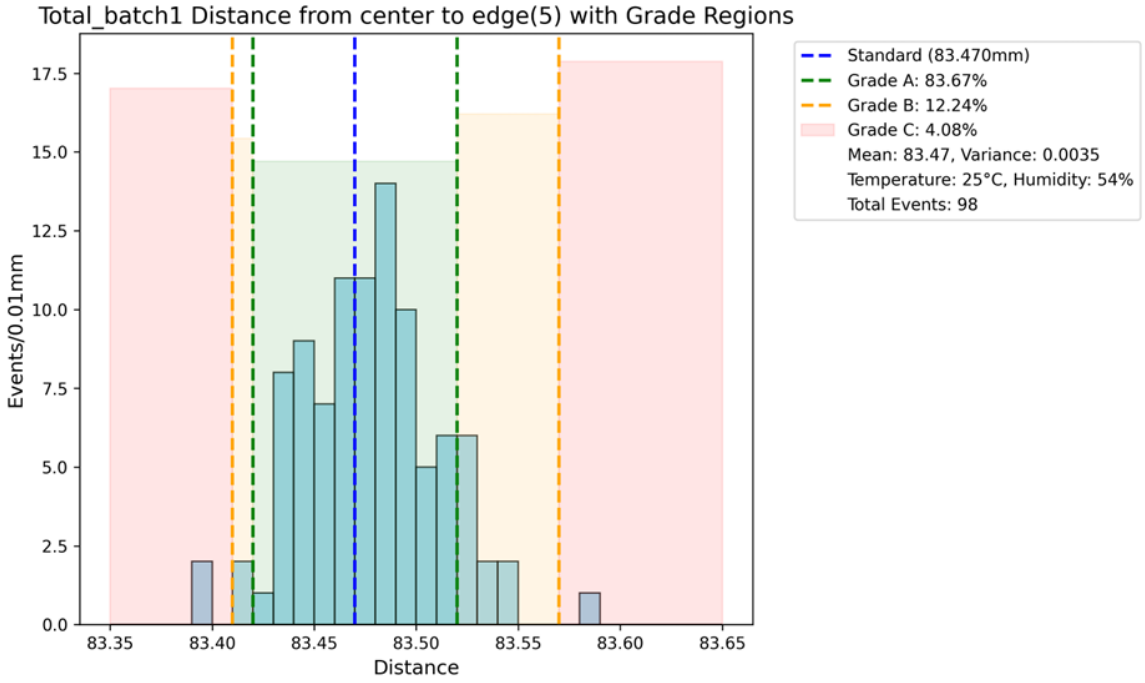

Total_batch1 Position of Notches(2) with Grade Regions
Standard (91.500mm)
Grade A: 100.00%
Grade B: 0.00%
Grade C: 0.00%
Mean: 91.50, Variance: 0.0002
Temperature: 25°C, Humidity: 54%
Total Events: 1200
Grade B codes: None
Grade C codes: None
Events/0.02mm
Position of Notches

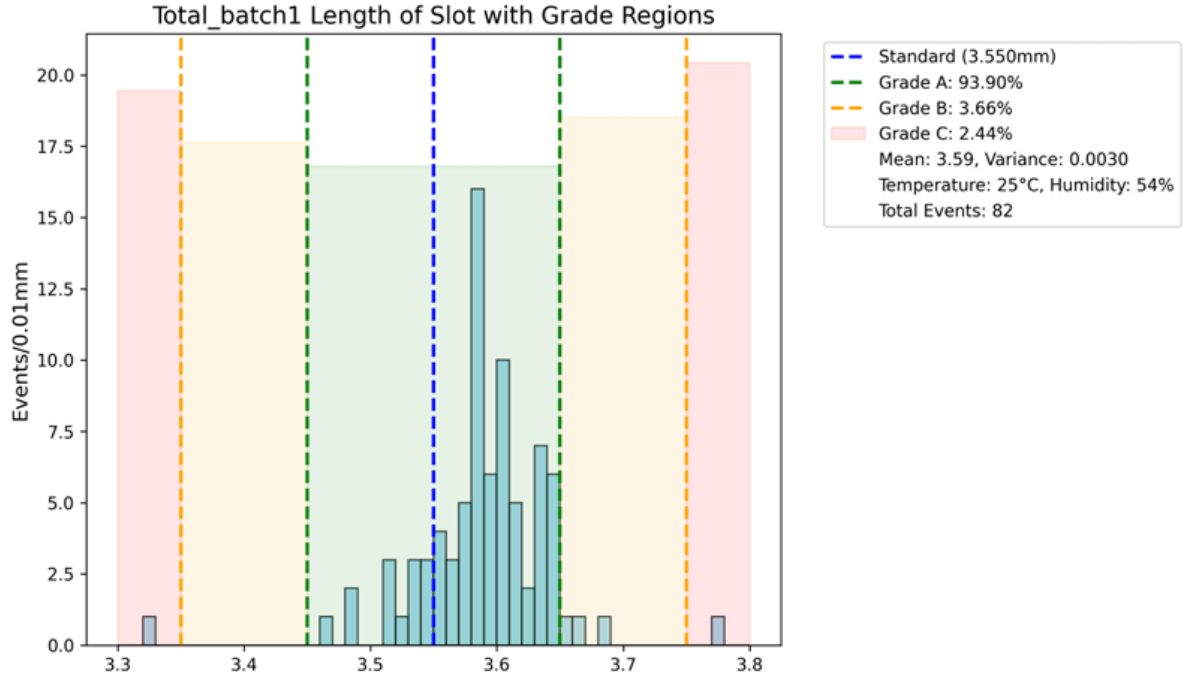

Total_batch1 Width of Mousebite Edge(1) with Grade Regions
Events/0.02mm
Width of Mousebite Edge
0
100
200
300
400
500
600
700
93.6
93.7
93.8
93.9
94.0
94.1
94.2
Standard (93.880mm)
Grade A: 100.00%
Grade B: 0.00%
Grade C: 0.00%
Mean: 93.89, Variance: 0.0003
Temperature: 25°C, Humidity: 54%
Total Events: 1200
Grade B codes: None
Grade C codes: None

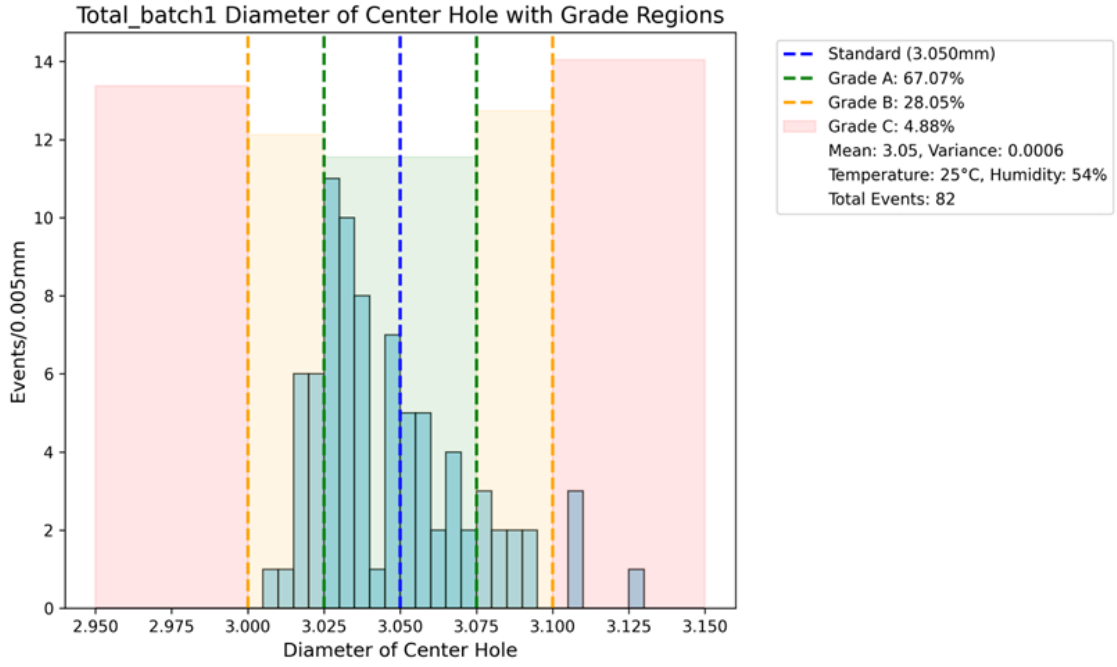

Total_batch1 Width of Mousebite Edge(2) with Grade Regions
Events/0.02mm
Width of Mousebite Edge
0
100
200
300
400
500
600
700
93.6
93.7
93.8
93.9
94.0
94.1
94.2
Standard (93.880mm)
Grade A: 100.00%
Grade B: 0.00%
Grade C: 0.00%
Mean: 93.89, Variance: 0.0002
Temperature: 25°C, Humidity: 54%
Total Events: 1200
Grade B codes: None
Grade C codes: None

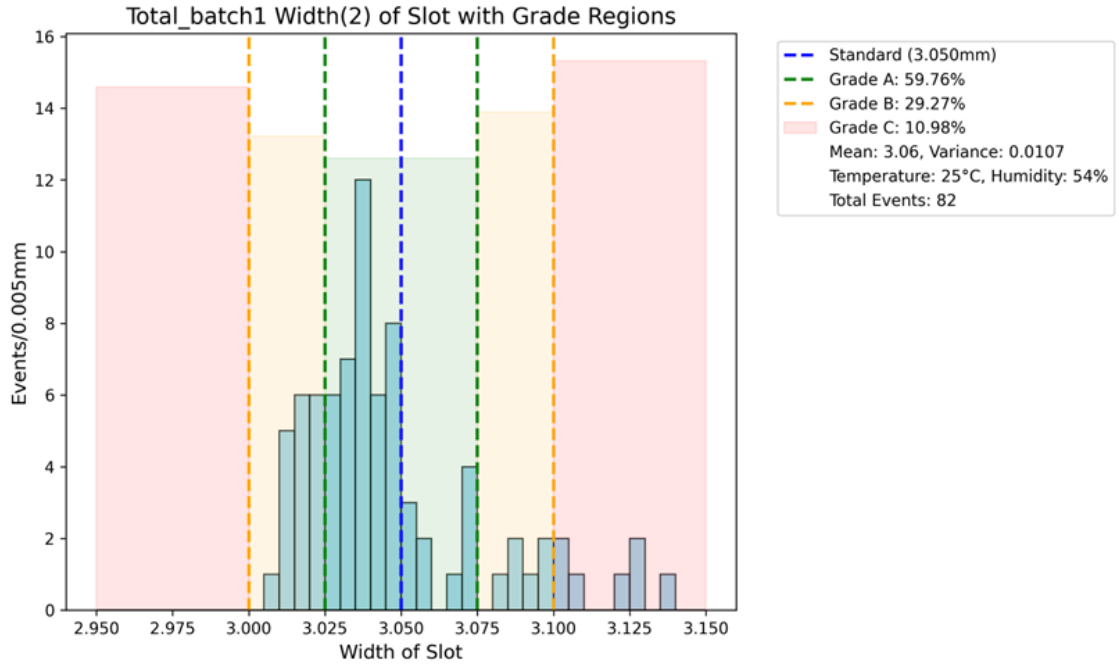
Summary table for IHEP measured result

Variables	Grade A	Grade B	Grade C	Possible reason
Length of Slot	93.90%	3.66%	2.44%	Part of the reason is our OGP use light mainly from top side, for holes with a rough edge when manufacturing it will be hard to identify outline and cause inaccuracy
Diameter of Center Hole	67.07%	28.05%	4.88%	
Width of Slot	59.76%	29.27%	10.98%	
Flatness	52.04%	47.96%	0%	Mainly due to the process to paste Kapton to CuW, which creates tension and causes flatness become worse
distance from center to edge	83.67%	12.24%	4.08%	Same error caused by OGP recognition, which bring deviation to center position and influence this distance value
distance from edge to opposite edge	100%	0%	0%	


Total_batch1 Distance from center to edge(5) with Grade Regions
Standard (83.470mm)
Grade A: 83.67%
Grade B: 12.24%
Grade C: 4.08%
Mean: 83.47, Variance: 0.0035
Temperature: 25°C, Humidity: 54%
Total Events: 98
Events/0.01mm
Distance


Total_batch1 Length of Slot with Grade Regions
Standard (3.550mm)
Grade A: 93.90%
Grade B: 3.66%
Grade C: 2.44%
Mean: 3.59, Variance: 0.0030
Temperature: 25°C, Humidity: 54%
Total Events: 82
Events/0.01mm


Total_batch1 Diameter of Center Hole with Grade Regions
Standard (3.050mm)
Grade A: 67.07%
Grade B: 28.05%
Grade C: 4.88%
Mean: 3.05, Variance: 0.0006
Temperature: 25°C, Humidity: 54%
Total Events: 82
Events/0.005mm
Diameter of Center Hole


Total_batch1 Width(2) of Slot with Grade Regions
Standard (3.050mm)
Grade A: 59.76%
Grade B: 29.27%
Grade C: 10.98%
Mean: 3.06, Variance: 0.0107
Temperature: 25°C, Humidity: 54%
Total Events: 82
Events/0.005mm
Width of Slot

Production plan

- Factory's production capacity:
- ~4 months producing 4000 CuW baseplates
- 6~8 months producing 17000 CuW baseplates
- Most of the CuW baseplates(~90%) will be produced using the IHEP method.

Production plan A

- **Details of production are still under discussion**

- **IHEP**
  - Industrial production, including lamination
  - 13822 full-pattern pieces
  - Production time ~230 days or 32 weeks
  - 2000/week from week 21
- **Madras**
  - Procurement and machining of CF baseplates
  - 10962 full and partials
  - Personnel for lamination
- **CIEMAT**
  - Machining of CuW partials LD-5 and HD-Bottom
  - 1008 pieces
  - Personnel for lamination
- **KIT**
  - Machining of remaining CuW partials and CF baseplates
  - 1562 CuW partials
  - Lamination of all partial CuW and CF baseplates