CuW baseplate R&D and production

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On behalf of Chinese HGCal Group

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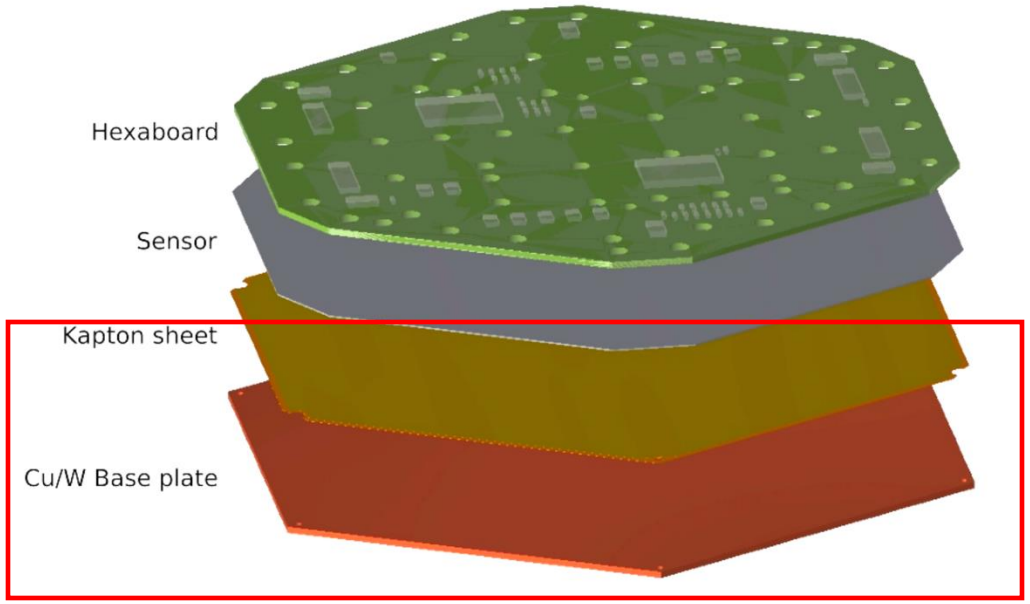
Outline:

1. CuW baseplate introduction & production status
2. Irradiation test, peel test, mechanics study and heat flow study for IHEP baseplates
3. Future production plan

CuW baseplate introduction & production status

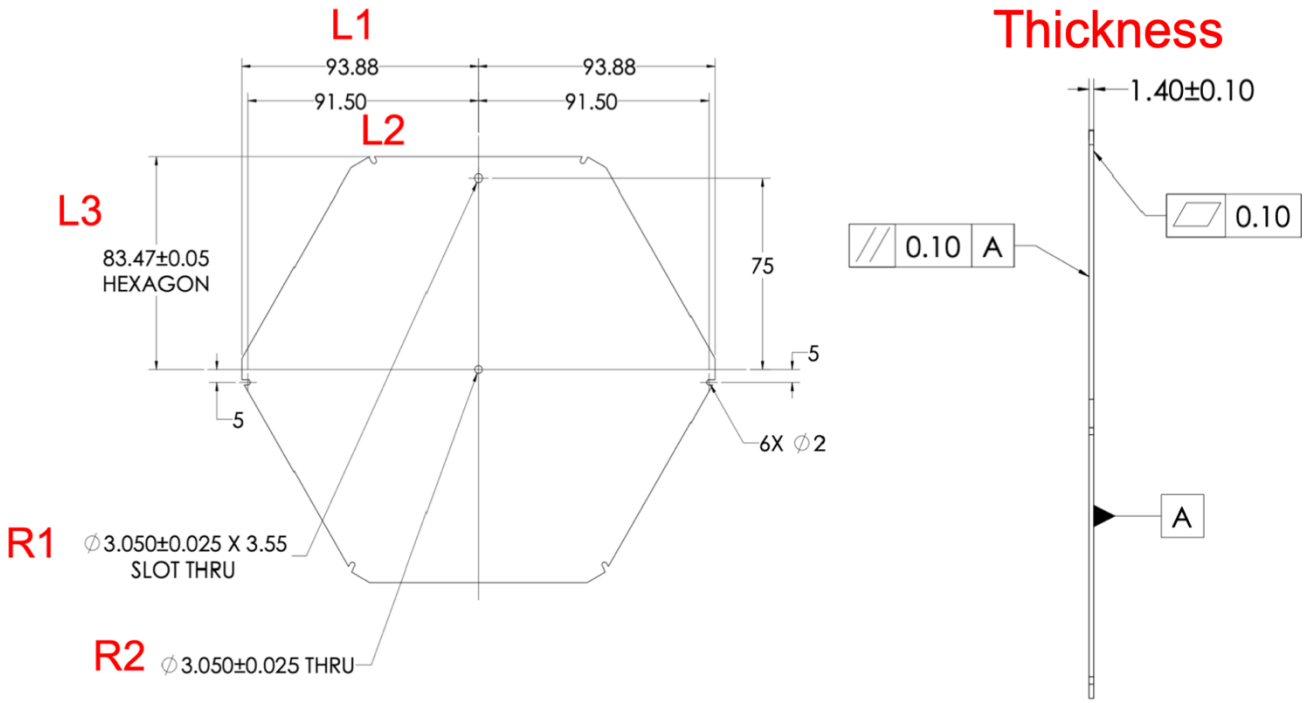
CuW baseplate introduction

- 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.
- Participating entities: IHEP, THU, ZJU, FDU, NNU.



Complete HGCal module

Complete CuW baseplate



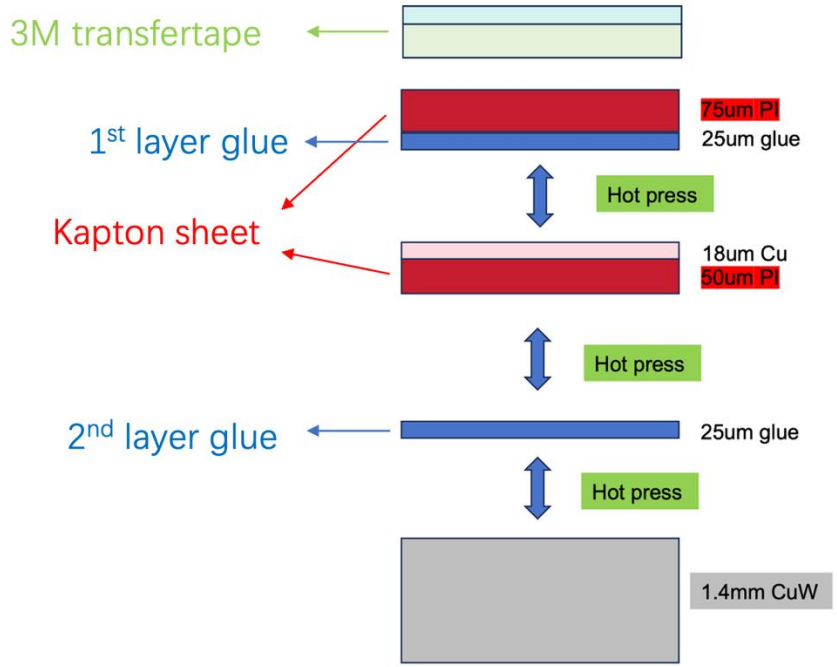
CuW baseplate design

Introduction of KIT plan and IHEP plan

- 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.

KIT plan's glue pattern

- 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.



Comparison & advantage

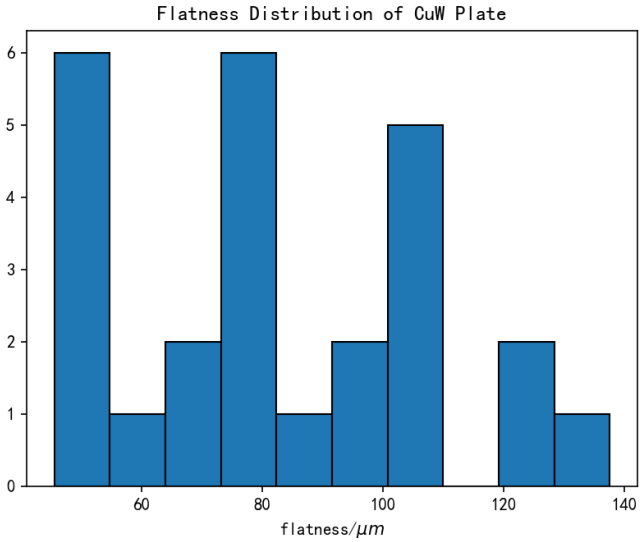
	KIT plan	IHEP plan	IHEP plan's advantage
Glue dispensing pattern	Partially-overlapping glue dispensing pattern.	Fully-overlapping glue dispensing pattern.	Have larger glue coverage area.
Bonding method	Laminate using pressure.	Hot pressing process.	
Production method	Laboratory production.	Industrial production.	Capable of 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 of CuW baseplate produced:

- 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.

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



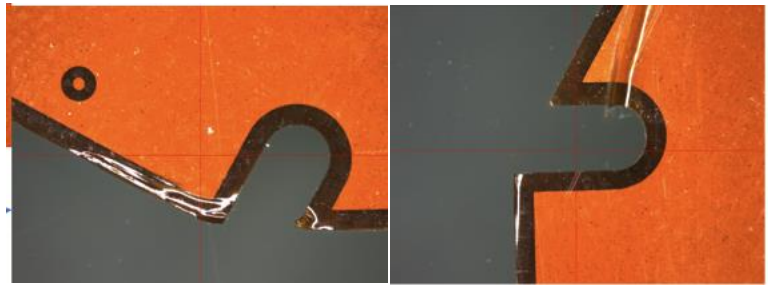
3rd batch's flatness (target: <100 um)

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

Irradiation test

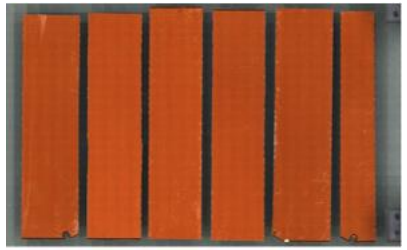
IHEP produced CuW baseplates have undergone 3 rounds of irradiation test and part of peel test.

- 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.



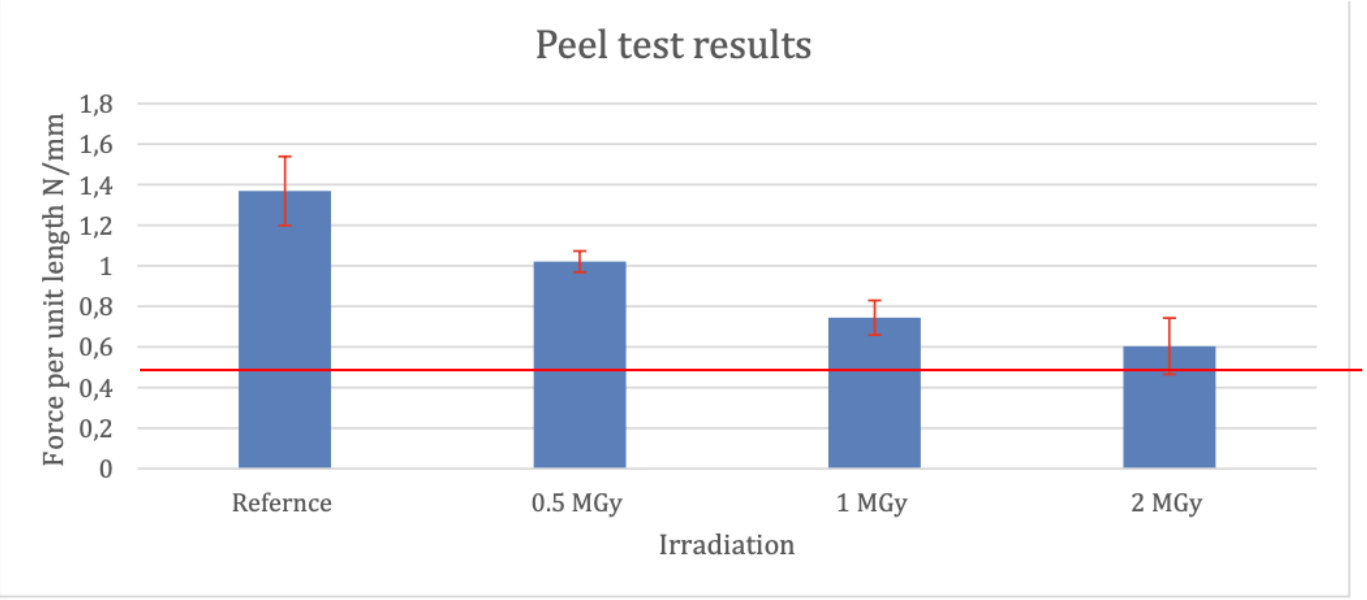
- 2nd round irradiation test
  - 2024.05 @KIT.
  - Integrated dose: 2 MGy.
  - Sample: new version IHEP baseplates(2 layers of same version glue).
  - Humidity control: done.
  - Heat-treated for 5 min at 170-180 ℃.
  - No delamination observed, only small defect appeared after heat treatment.

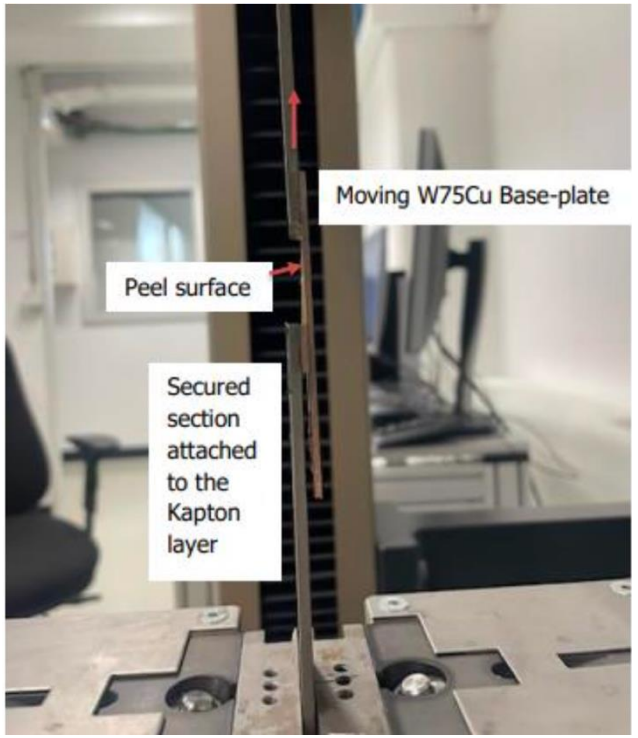
- 3rd round irradiation test
  - 2024.09 @CIEMAT.
  - Integrated dose: 0.5 MGy, 1 MGy, 1~2 MGy.
  - Sample: new version IHEP baseplates(2 layers of same version glue).
  - Humidity control: done.
  - No delamination observed.



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).

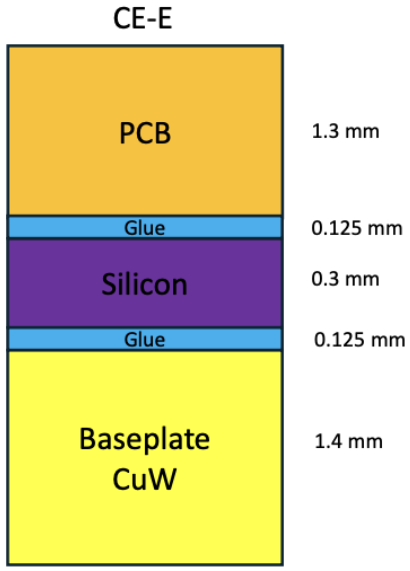




Mechanics study

- Motivation: when module cool down from room temperature to -35 $°C$, 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

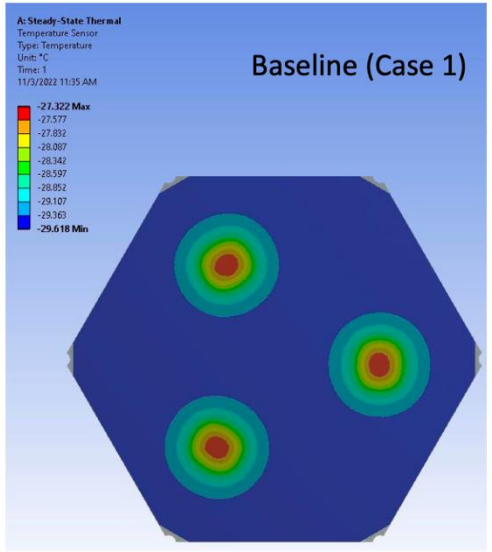
Heat flow study

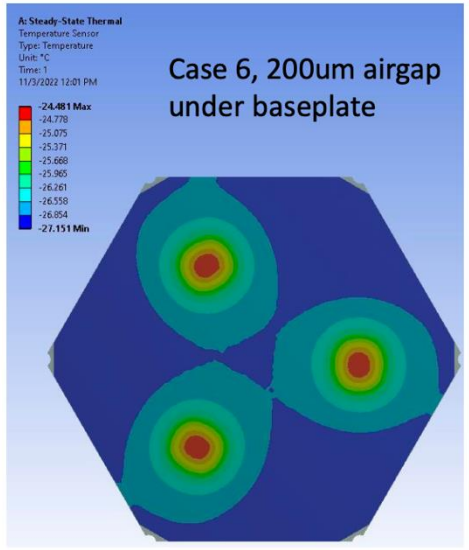
- Steady state thermal simulation of heat flow through the module.
- Determine sensor temperature and temperature gradient, using different airgaps and materials.
- Better flatness, smaller airgap, temperature distribution more uniform.
- All cases' max/min temperature and temperature gradient performed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

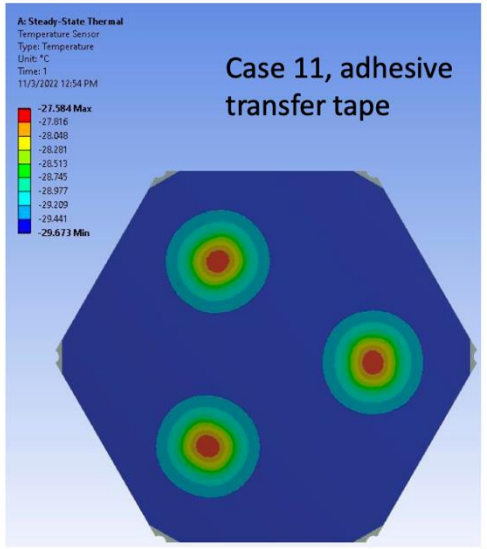
CE-E Results

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







Future production plan

Production plan & contract status

Production plan(tentative):

- IHEP:
  - Industrial production, including lamination.
  - ~13k full-pattern pieces.
  - Production time: ~230 days.
- KIT:
  - Machining of remaining CuW partials.
  - ~1.5k CuW partials.
  - Lamination of all partial CuW baseplates.

- IHEP industrial 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.

Contract status:

- CERN's K-contract:
  - CERN's K-contract has been signed.
- Industrial production contract:
  - The production contract with the factory is in the process of being signed.

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:
  - 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.
- Future production plan:
  - IHEP will produce most of CuW baseplates(~90%).
  - CERN's K-contract and industrial production contract is in the process of being signed.

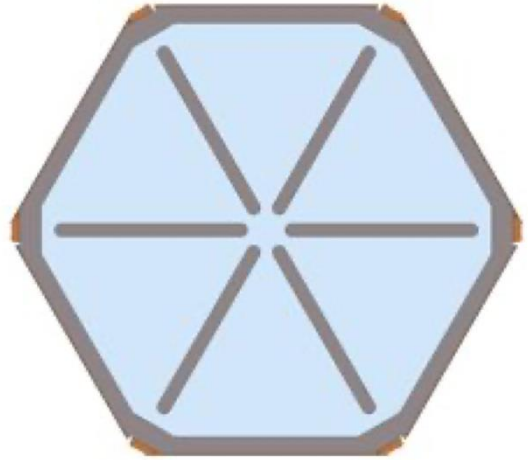
Thanks

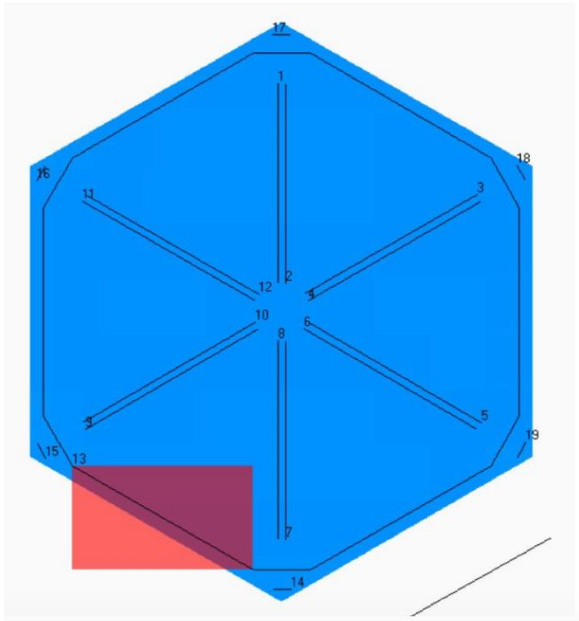
Backup

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.

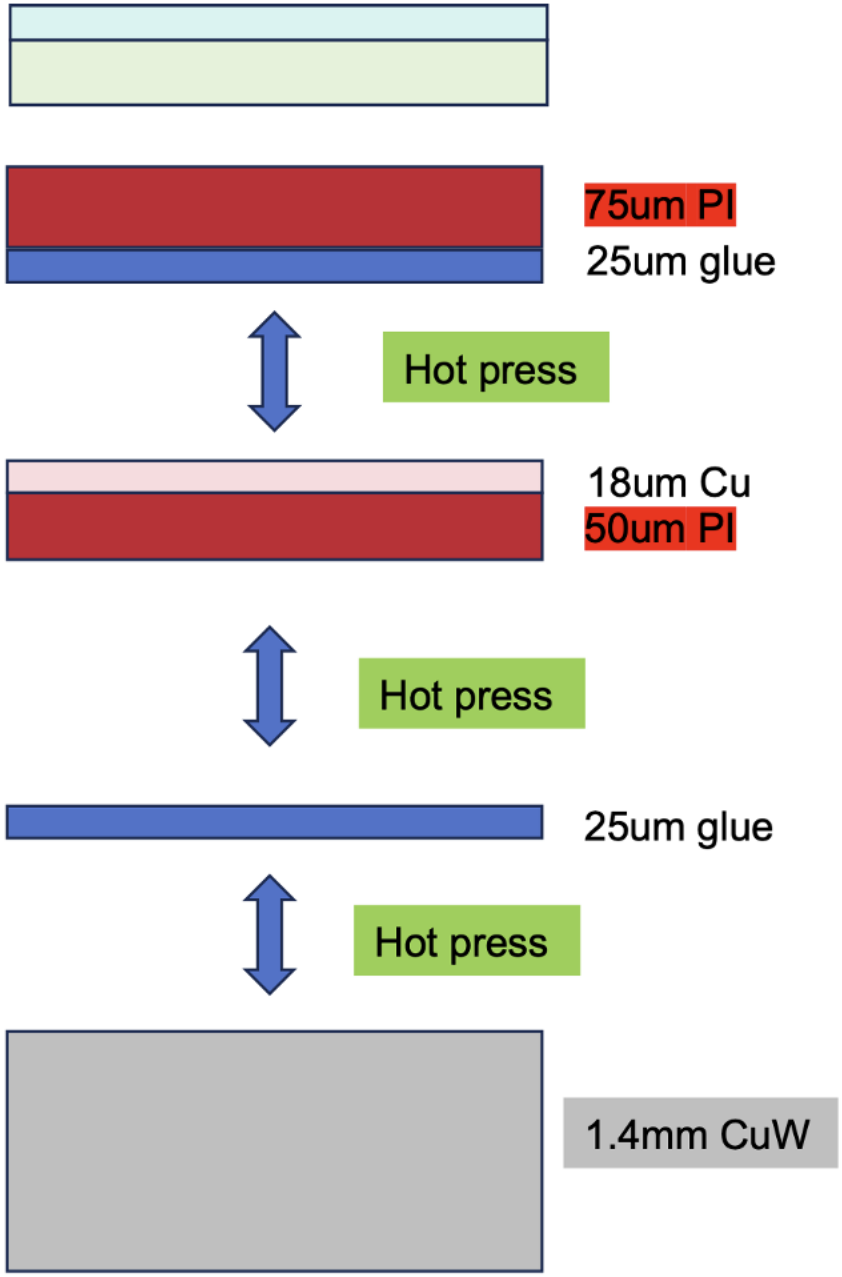




CuW Baseplate production status

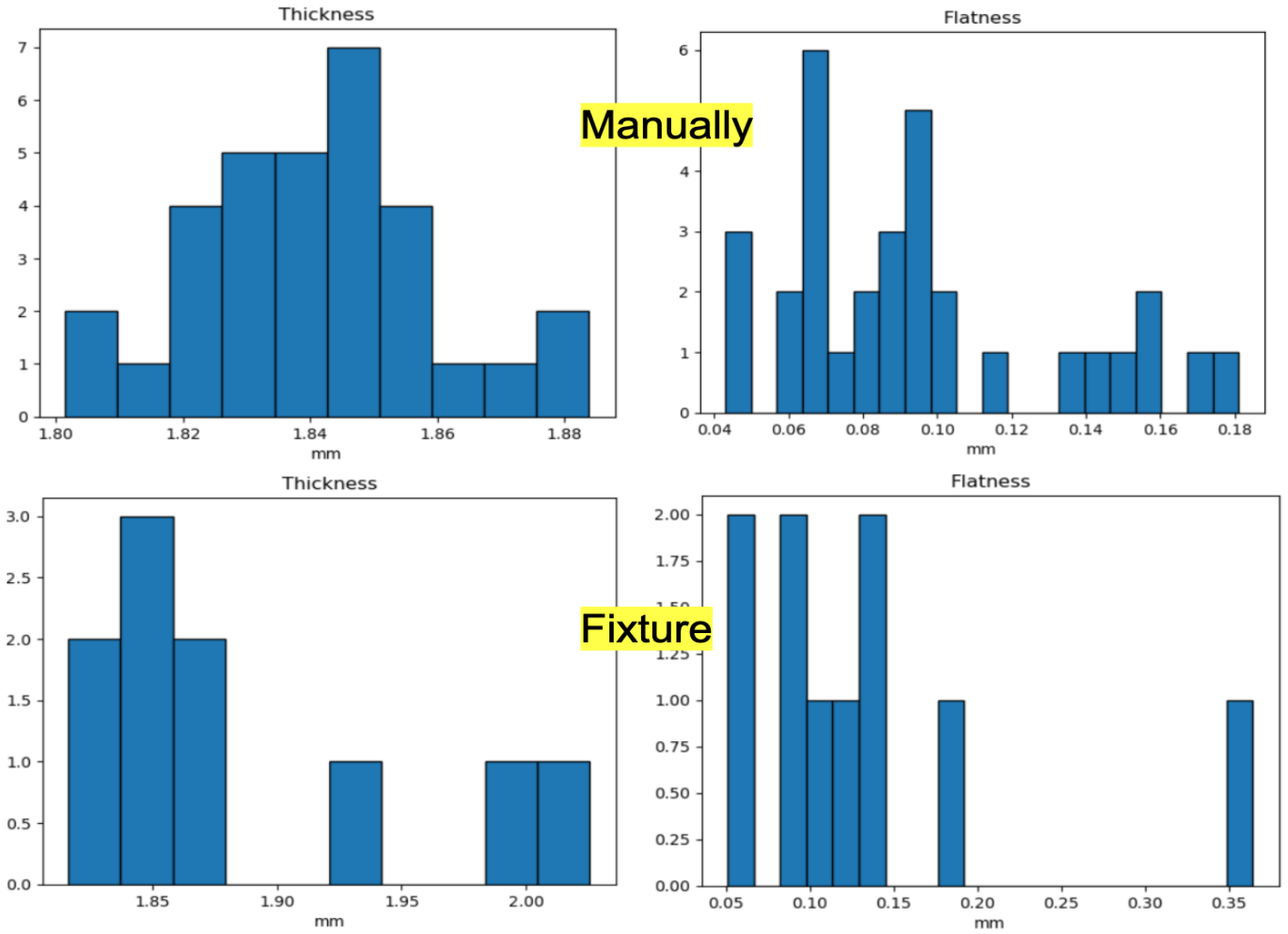
IHEP Kapton assembly process :

- 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℃.

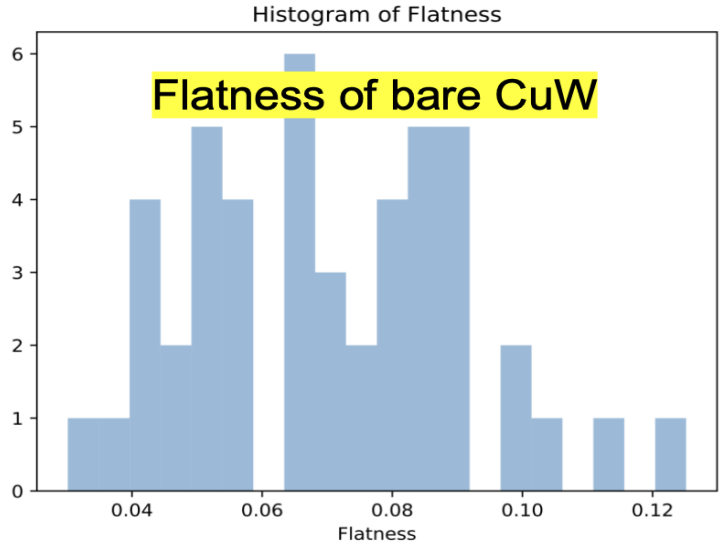


2nd batch's baseplates detail

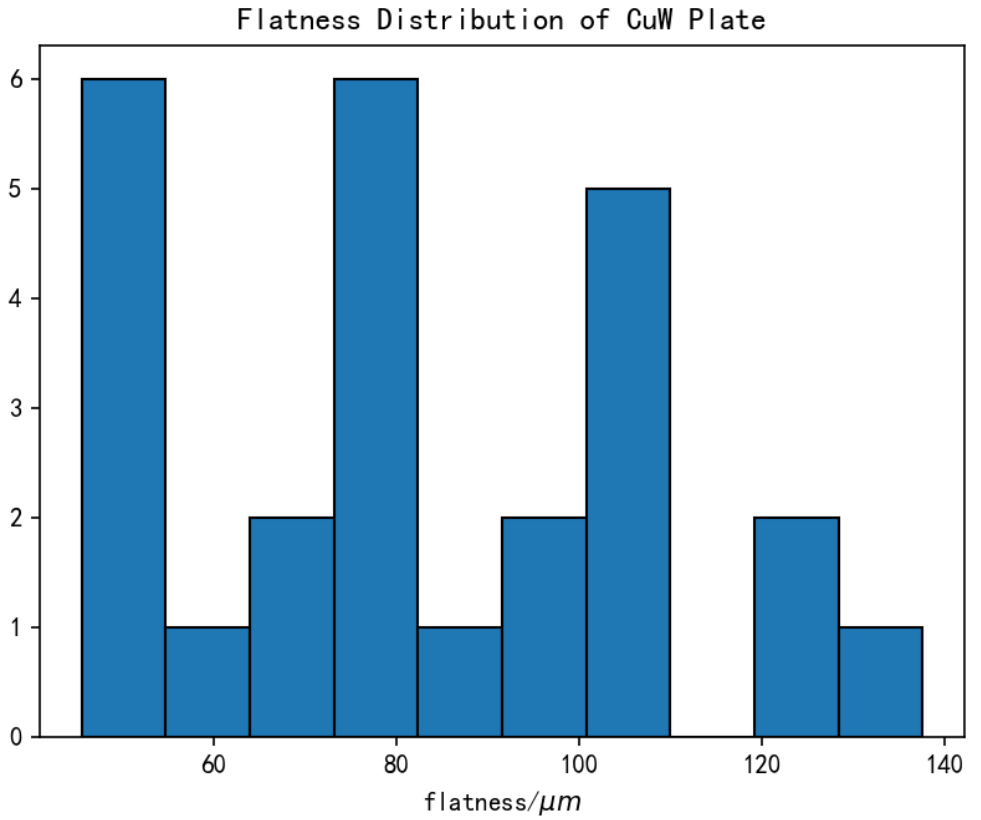
Thickness & Flatness



- The flatness and thickness measurements were taken from the side with 3M tape including cover paper.
- Overall, the flatness of manually applied Kapton layer is better than that applied using fixtures: ~70% of 31 CuWs have a flatness ≤ 100 microns.



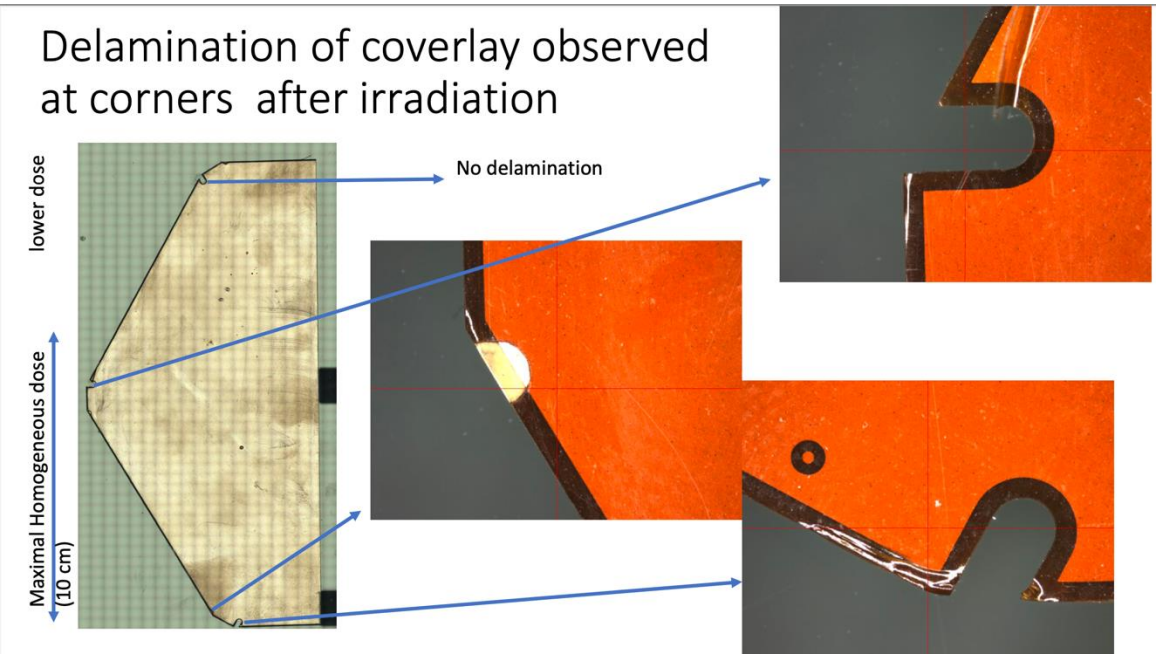
3rd batch's baseplates detail



- New batch of 30 CuW baseplates
  - Lamination with Kapton foil and transfer tape: done
  - The flatness of them less than 150 mm (unconstrained)
  - 2 baseplates use the epoxy adhesive for each layer of kapton and CuW baseplate lamination in hot press. (sent to CERN in last month for irradiation test)
  - 28 baseplates use the epoxy adhesive only for between kapton and CuW baseplate lamination (for module production)
- Shipment
  - 7 CuW baseplates sent to NTU last week

Irradiation test

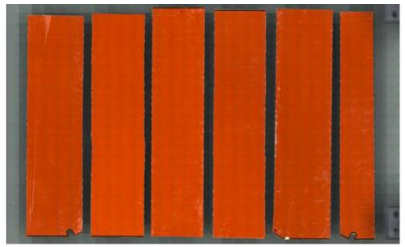
- Irradiation test @CIEMAT: May 2024 and Sept 2024



- 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)



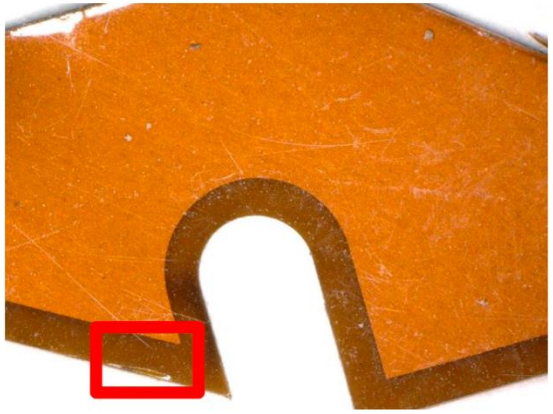
- 2nd test in Sept. 2024:
- Humidity control: done
- Irradiated to 0.5MGy,1MGy, 1~2MGy
- No delamination observed
- Peel test will be done @CERN

Irradiation test

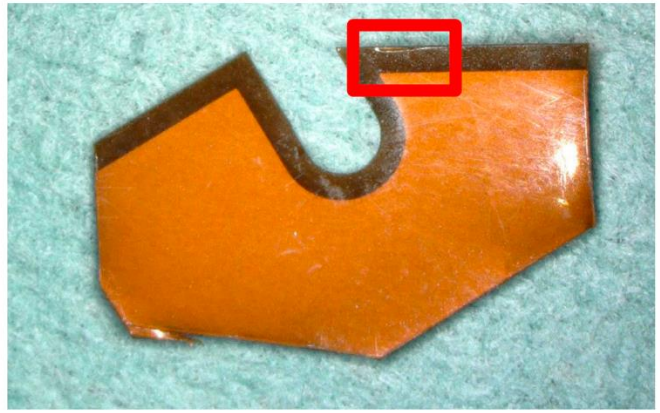
- Irradiation test @KIT: May. 2024
- Irradiation of heat-treated “IHEP” type Kapton to 2 MGy after 5 minutes at 170 - 180 ℃
- No delamination observed
- Only small defect appeared after heat treatment

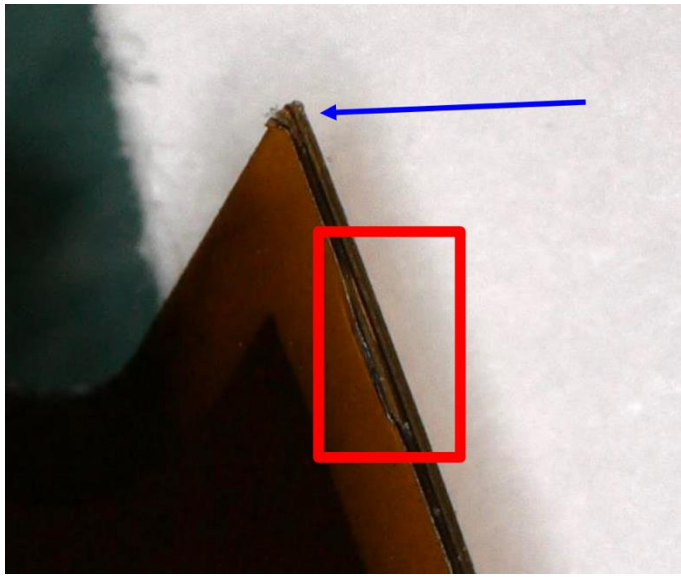
Before

After heat-treatment



After irradiation





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