高粒度量能器硅模块集成工艺介绍

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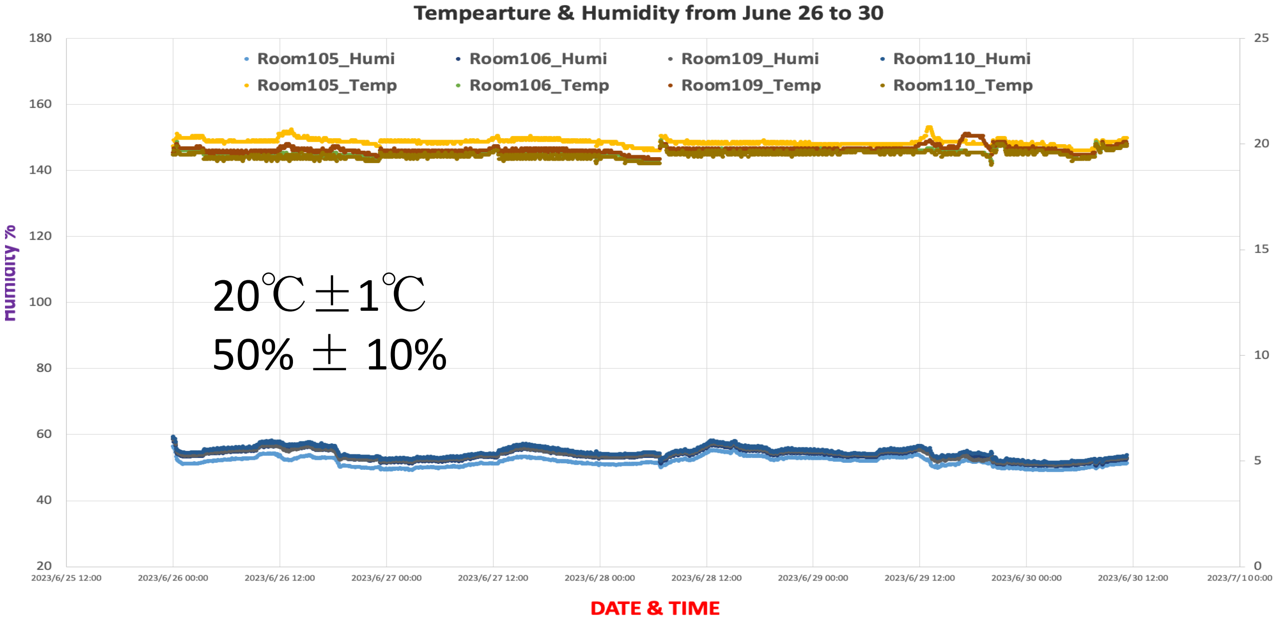
报告内容

- ❑ HGCal硅模块生产
  - ESD保护
  - 模块生产工艺介绍
- ❑ 总结及展望

CMS-HGCal: 高粒度量能器组装中心

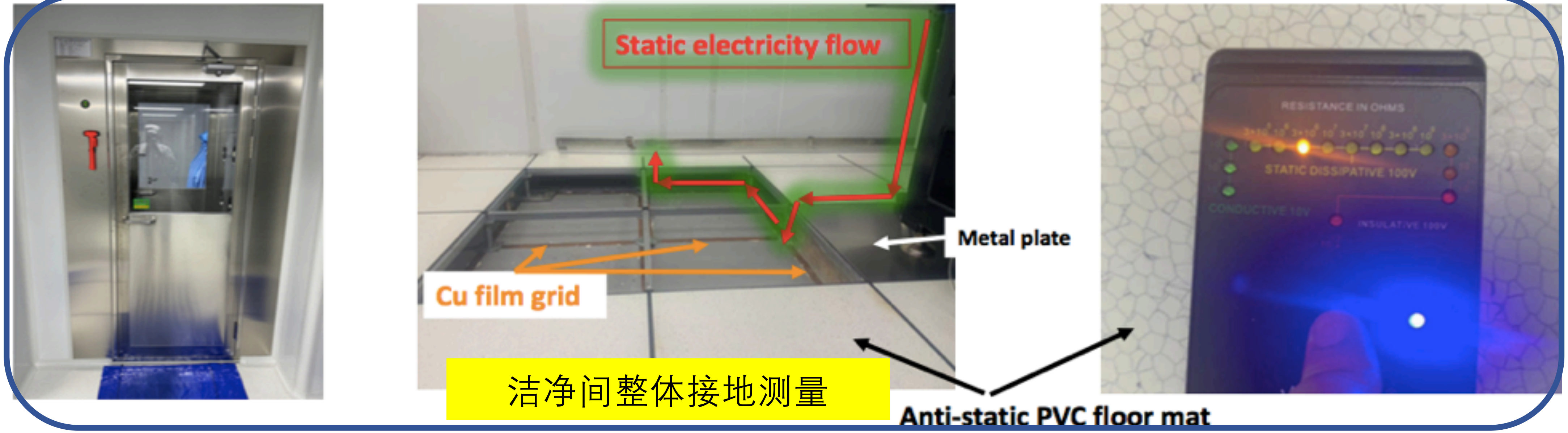


□ 在高能所搭建完成了面积为140m²的千级恒温恒湿洁净间，目前已连续运行三年。

□ 温湿度控制和洁净度度控制满足要求。

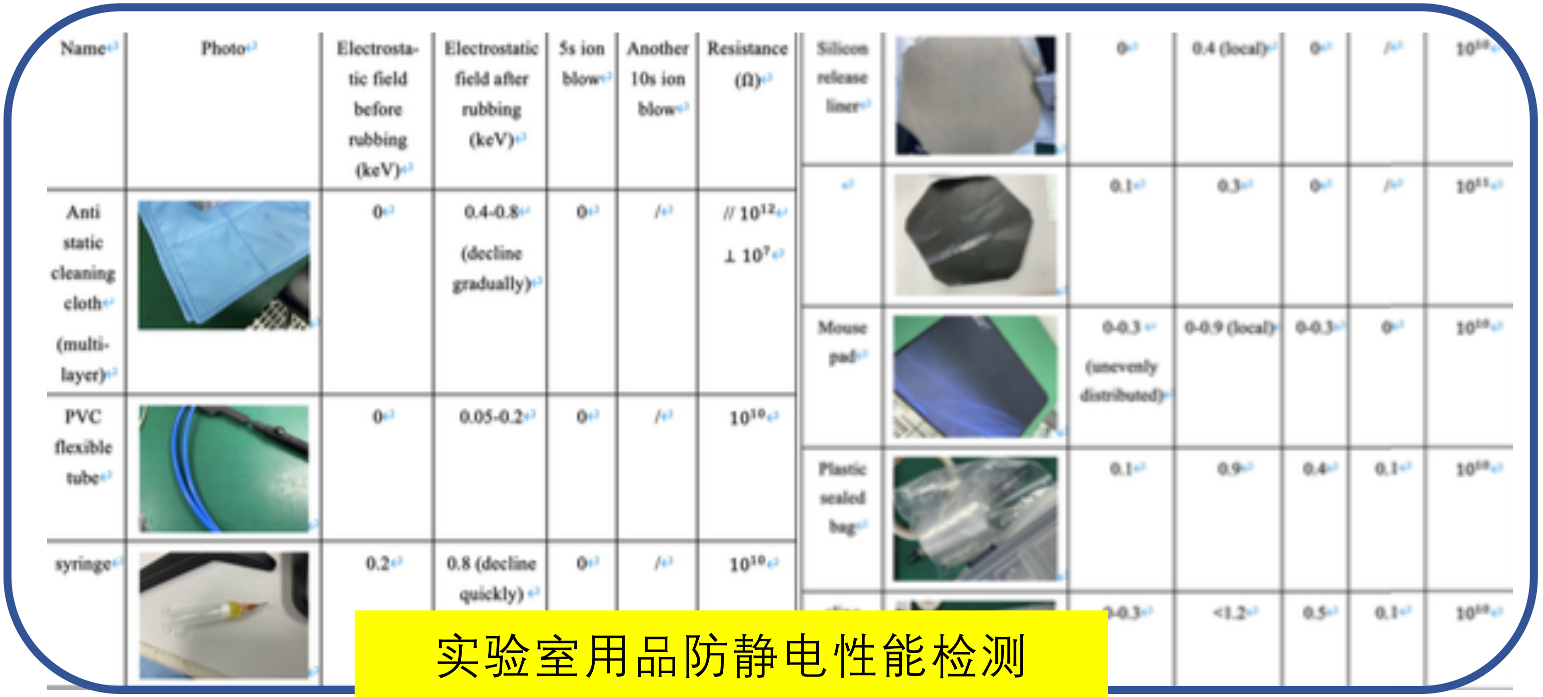
□ 洁净间整体及设备等做了接地。

CMS-HGCal: ESD保护


Static electricity flow
Cu film grid
Metal plate
RESISTANCE IN OHMS
STATIC DISSIPATIVE 100V
CONDUCTIVE 10V
INSULATIVE 100V
Anti-static PVC floor mat

洁净间整体接地测量

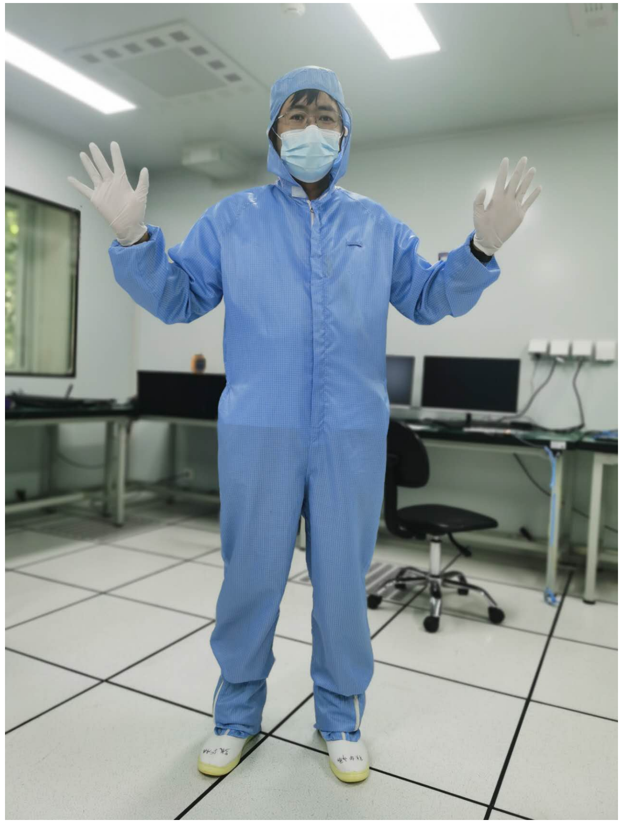
- □ 洁净间墙壁地板均为防静电材料，并且与洁净间外接地连通
- □ 我们利用表面电阻测量仪对实验室绝大部份用品进行测量，按照防静电标准进行分类，对不满足防静电要求的物品进行替换

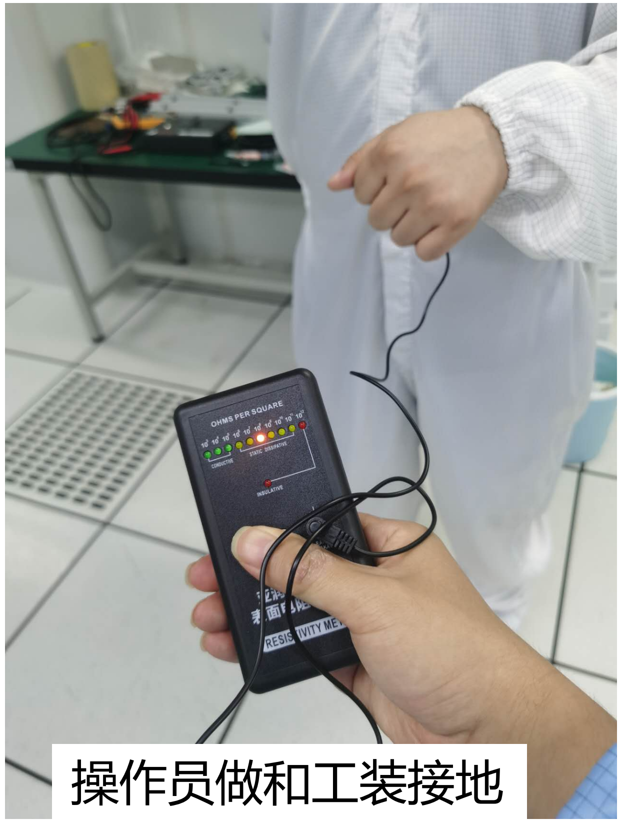


Name	Photo	Electrostatic field before rubbing (keV)	Electrostatic field after rubbing (keV)	5s ion blow	Another 10s ion blow	Resistance (Ω)
Anti static cleaning cloth (multi-layer)		0	0.4-0.8 (decline gradually)	0	/	// 10^{12} ⊥ 10^{7}
PVC flexible tube		0	0.05-0.2	0	/	10^{10}
syringe		0.2	0.8 (decline quickly)	0	/	10^{10}
Silicon release liner		0	0.4 (local)	0	/	10^{10}
		0.1	0.3	0	/	10^{11}
Mouse pad		0-0.3 (unevenly distributed)	0-0.9 (local)	0-0.3	0	10^{10}
Plastic sealed bag		0.1	0.9	0.4	0.1	10^{10}
		0-0.3	<1.2	0.5	0.1	10^{10}

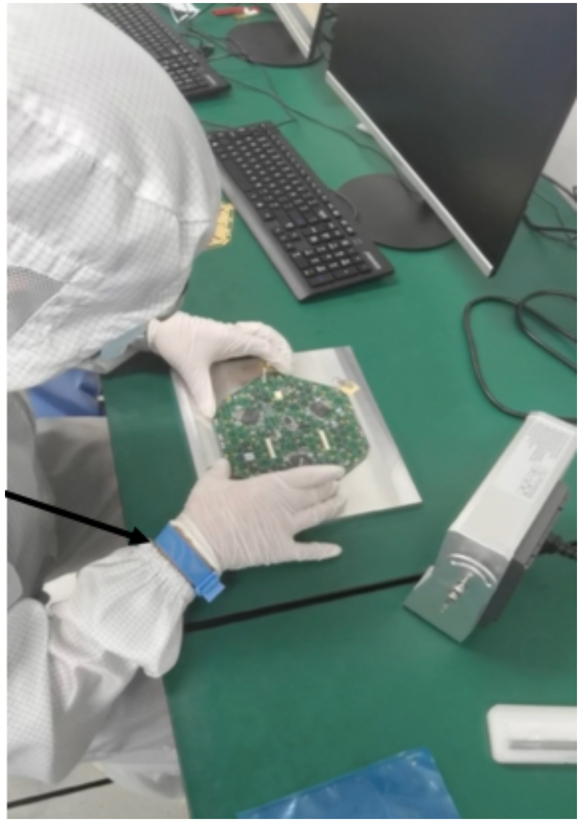
实验室用品防静电性能检测

CMS-HGCal: ESD保护




OHMS PER SQUARE
CONDUCTIVE
STATIC DISSIPATIVE
INSULATIVE
表面电阻
RESIS IVITY ME

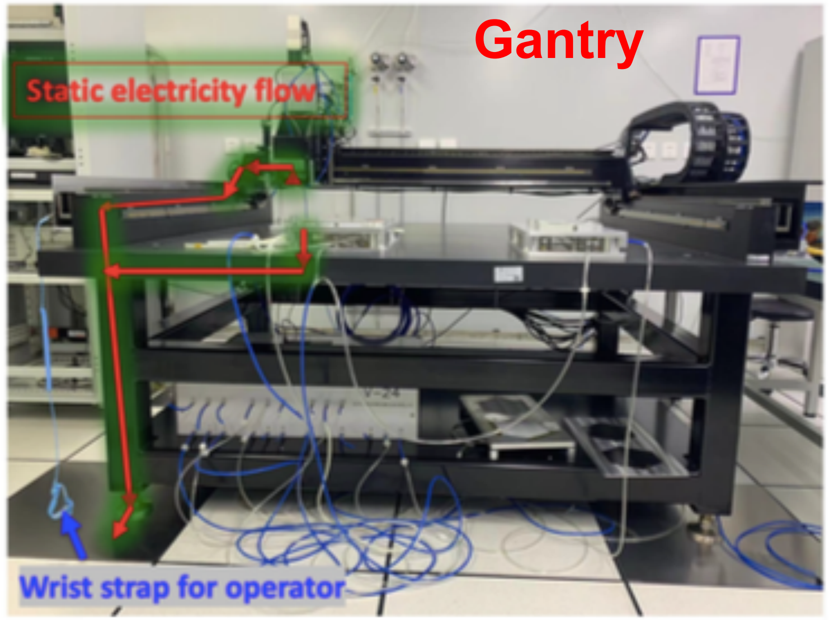
操作员做和工装接地



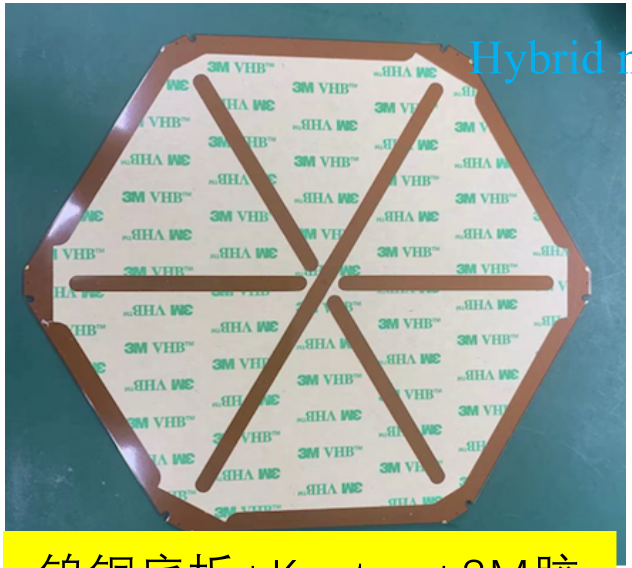
- 我们检查了实验室人员工作时的接地情况。在目前的条件下，人员通过洁净服可以实现与洁净间共地
- 在操作hexaboard和模块时，相应的工装也做了接地，同时用离子风扇全程打开。

CMS-HGCal: 硅模块高精度组装工艺

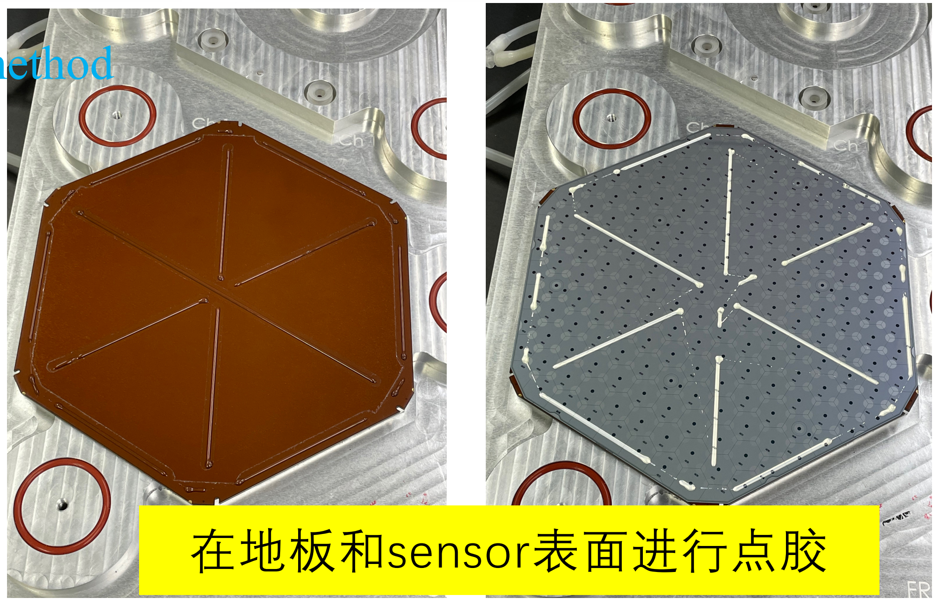
Module assembly by gantry → Wire bonding → Encapsulation → Electronic test


Gantry
Static electricity flow
Wrist strap for operator

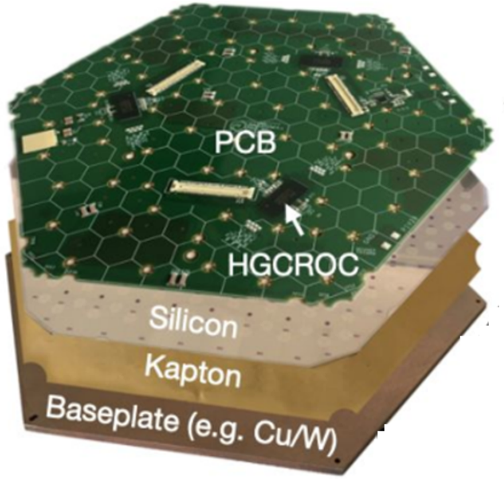
Hybrid method



钨铜底板+Kapton+3M胶



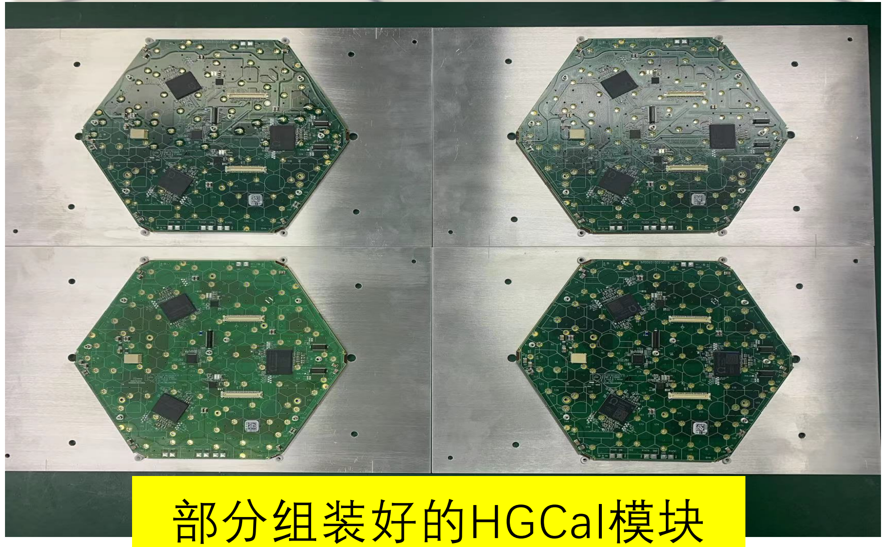
在地板和sensor表面进行点胶


PCB
HGCROC
Silicon
Kapton
Baseplate (e.g. Cu/W)

- □ 硅模块结构：前端电子学板+硅传感器+ CuW底板
- □ Hybrid组装方案：模块每层之间利用3M胶（双面固体）+环氧树脂胶（液体）进行粘合
- □ 利用gantry完成点胶及前端电子学板和硅传感器的精确组装
- □ 已经实现全自动化组装过程

CMS-HGCal: 模块厚度控制

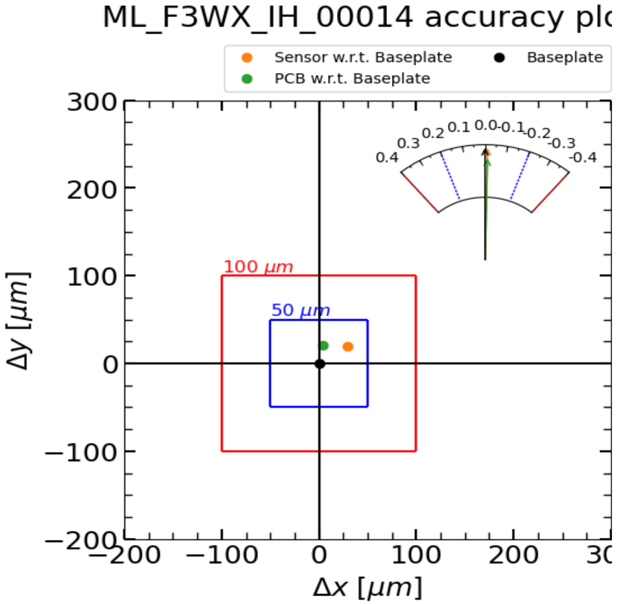
OGP
Static electricity flow

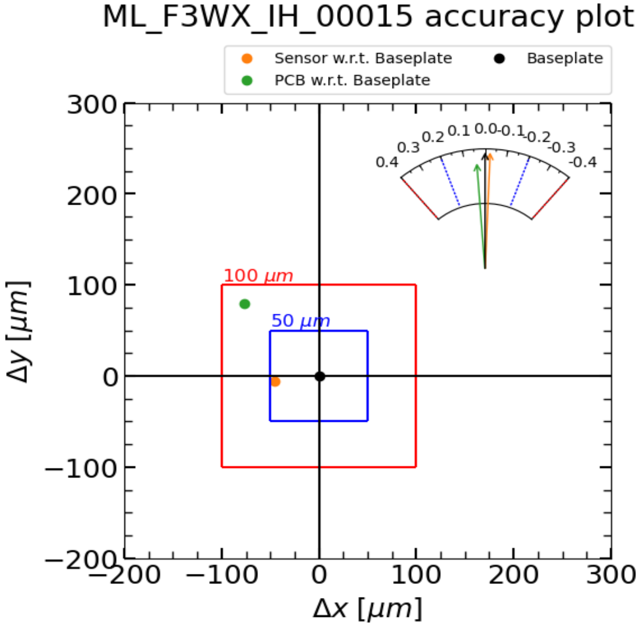

部分组装好的HGCal模块

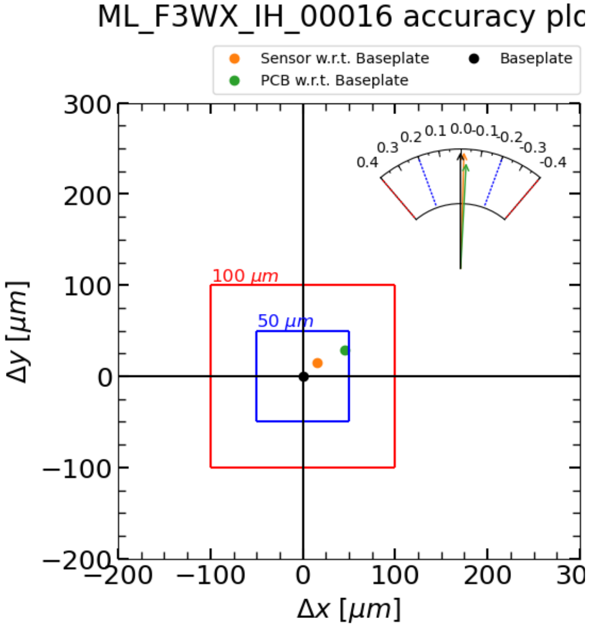
Module	Thickness mm	Flatness mm（<0.2）
ML_F3WX_IH_0014	3.650	0.071
ML_F3WX_IH_0015	3.645	0.123
ML_F3WX_IH_0016	3.656	0.102
ML_F3WX_IH_0017	3.631	0.082
ML_F3WX_IH_0018	3.635	0.101
ML_F3WX_IH_0019	3.645	0.128
ML_F3WX_IH_0020	3.638	0.068

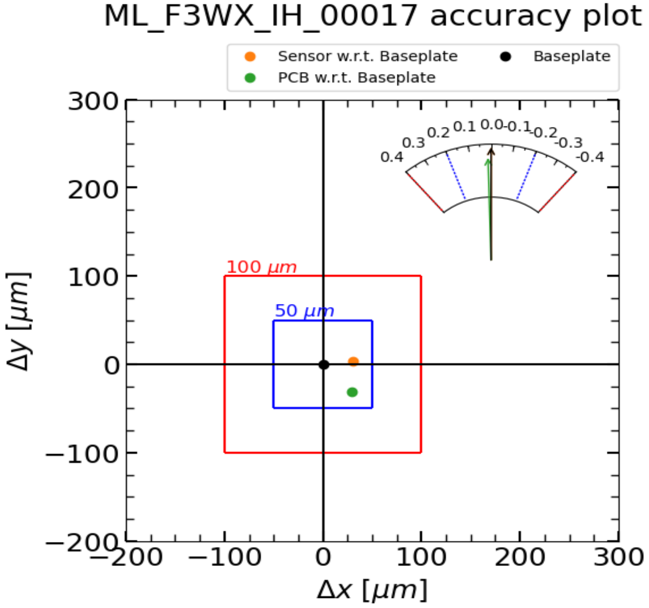
- 模块的厚度的一致性小于50μm
- 模块的平整度小于130μm

CMS-HGCal: 模块组装精度

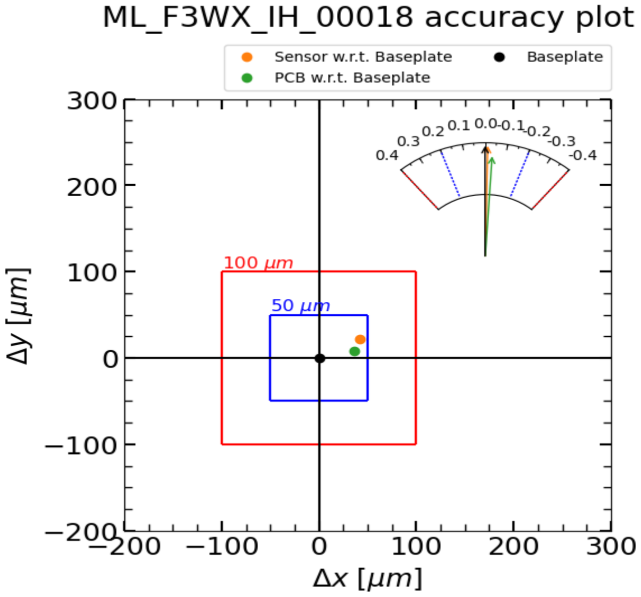

ML_F3WX_IH_00014 accuracy pl

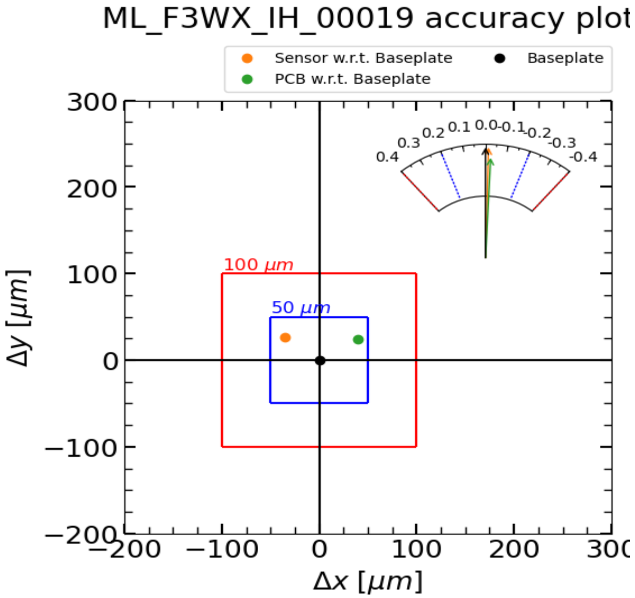

ML_F3WX_IH_00015 accuracy plot

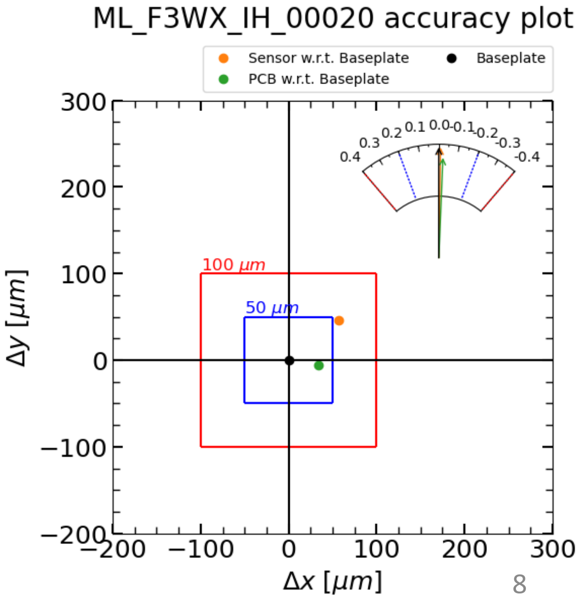

ML_F3WX_IH_00016 accuracy pl


ML_F3WX_IH_00017 accuracy plot

- □ 最近一个月完成了7个8英寸模块的组装
- □ 所有模块的对齐精度均满足要求（最大偏差77μm）

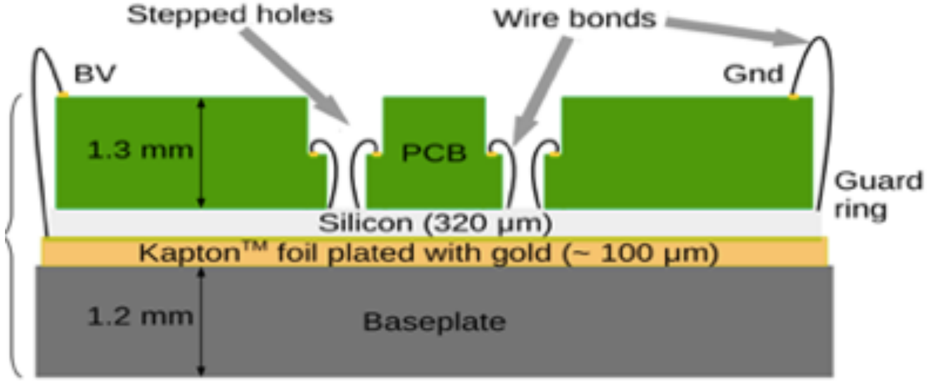

ML_F3WX_IH_00018 accuracy plot


ML_F3WX_IH_00019 accuracy plot

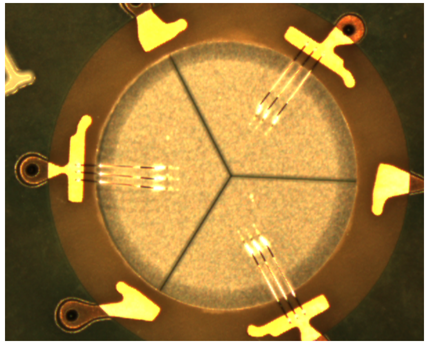

ML_F3WX_IH_00020 accuracy plot

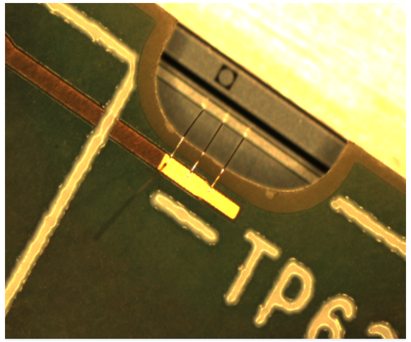
CMS-HGCal: 绑定

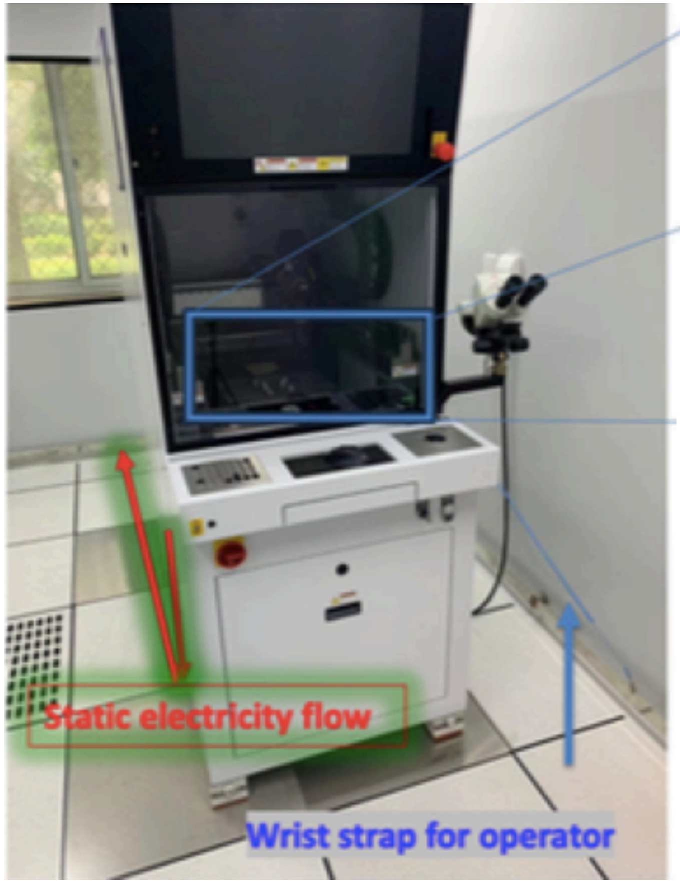
Module assembly by gantry → **Wire bonding** → Encapsulation → Electronic test



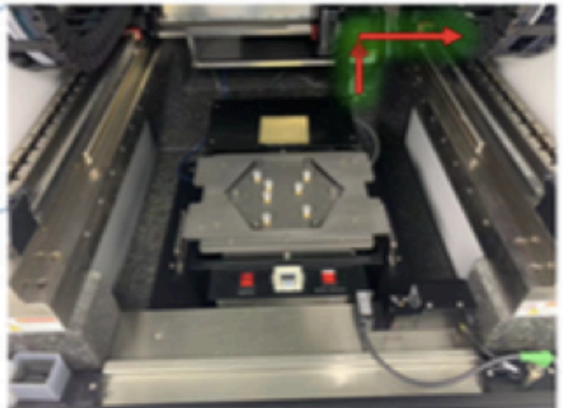
Stepped holes
Wire bonds
BV
Gnd
1.3 mm
PCB
Guard ring
Silicon (320 μm)
Kapton™ foil plated with gold (~ 100 μm)
1.2 mm
Baseplate

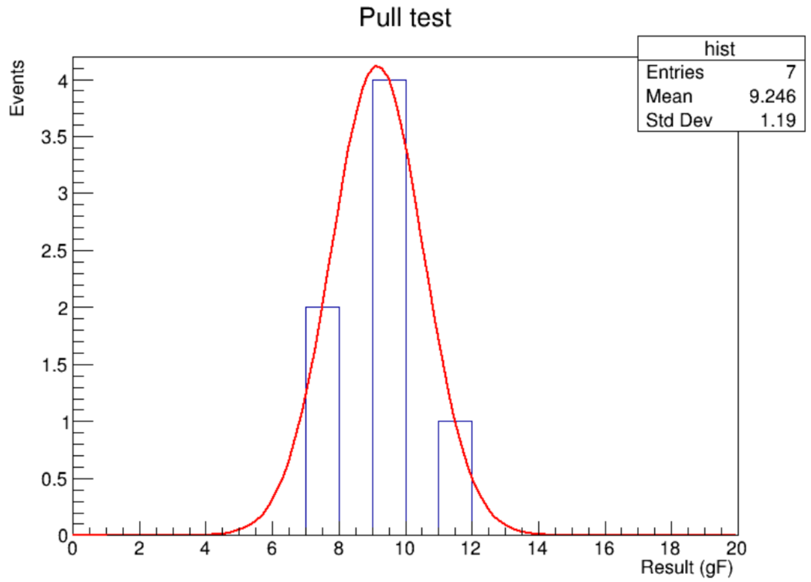






Static electricity flow
Wrist strap for operator

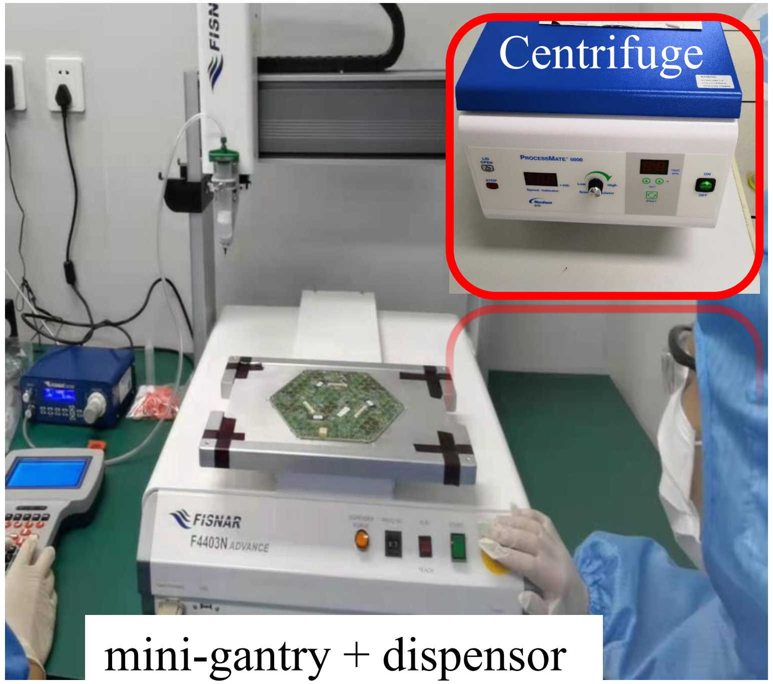


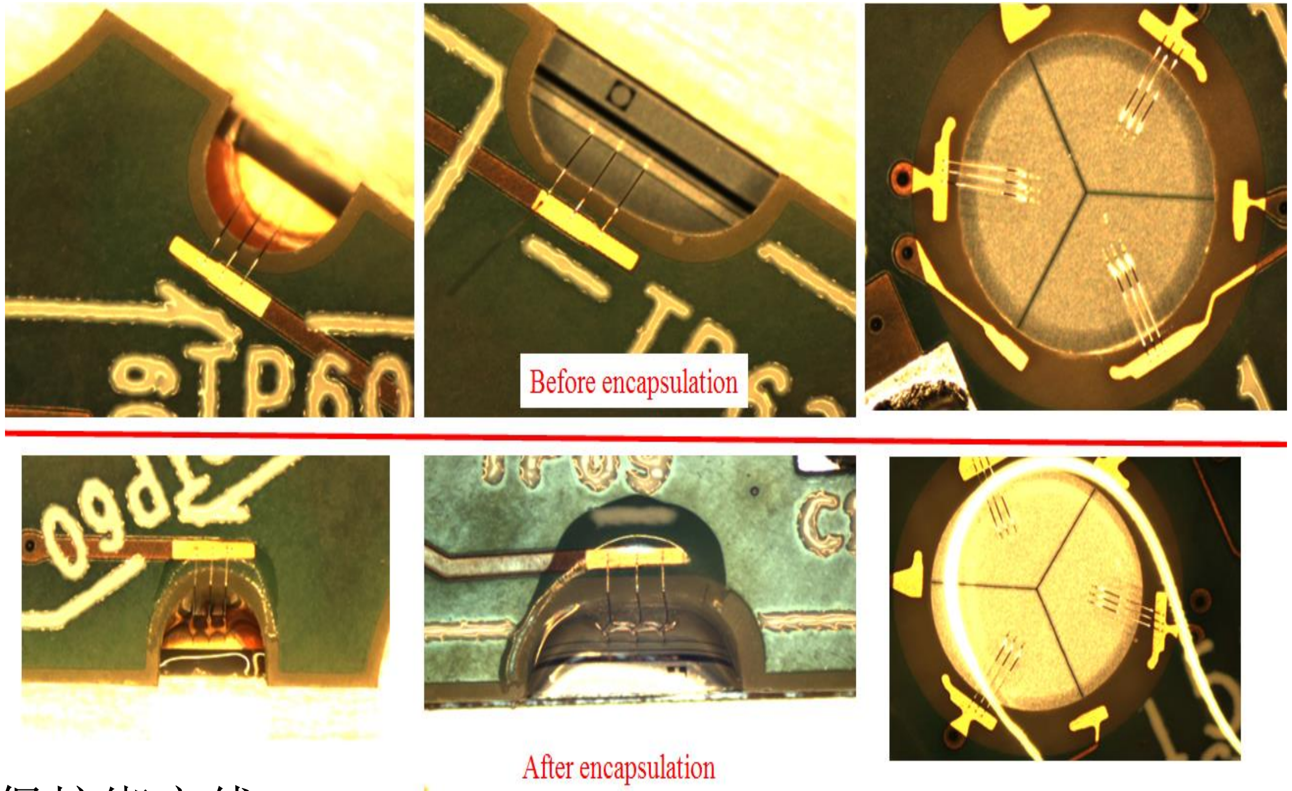


- 已经实现单个模块的自动化绑定
- 单根绑定线的可承受的拉力接近10g

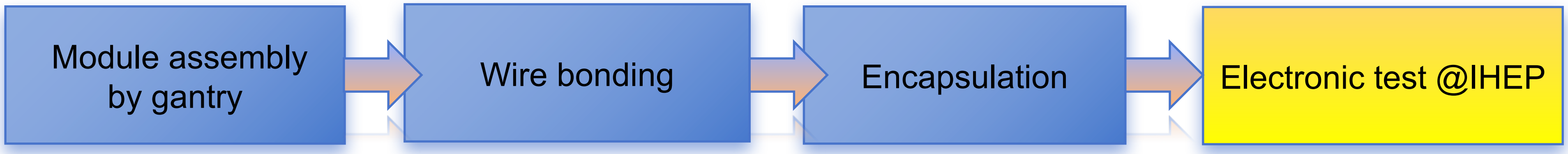
CMS-HGCal: 封装

Module assembly by gantry → Wire bonding → **Encapsulation** → Electronic test


Centrifuge
mini-gantry + dispensor


Before encapsulation
After encapsulation

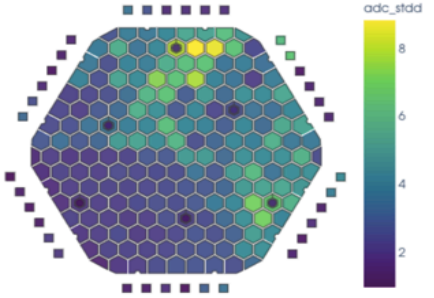
- 利用迷你gantry进行封装保护绑定线
- 封装过程已实现全自动化



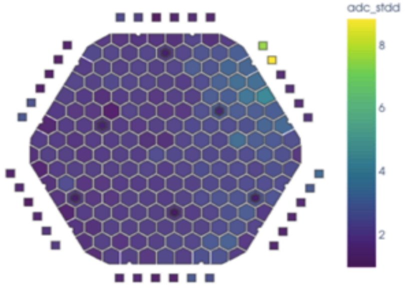
Module assembly by gantry → Wire bonding → Encapsulation → Electronic test @IHEP

Module number	Noise (No. of bad channel < 10)
ML_F3WX_IH_0014	√
ML_F3WX_IH_0015	√
ML_F3WX_IH_0016	√
ML_F3WX_IH_0017	√
ML_F3WX_IH_0018	√
ML_F3WX_IH_0019	√
ML_F3WX_IH_0020	√

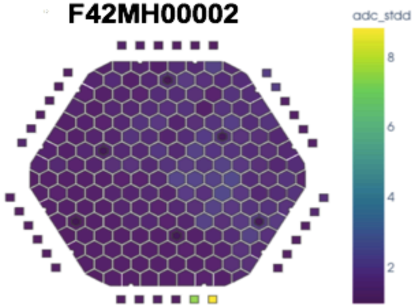
- 利用单模块测试系统在完成每一步组装工艺前后对模块电子学噪声进行测试，帮助优化组装工艺，提高成品率。
- 这一批次所有已完成的模块没有一个坏道。
- 单通道噪声最大为10ADC左右。目前从CERN得到的反馈可能是由于高能所teststand中DC-DC模块有问题，CERN正在重新发送一套DC-DC模块给高能所。



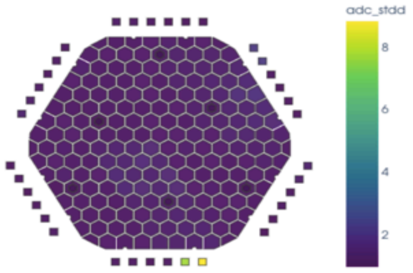
ML F3WXIH0014
F42MH00002



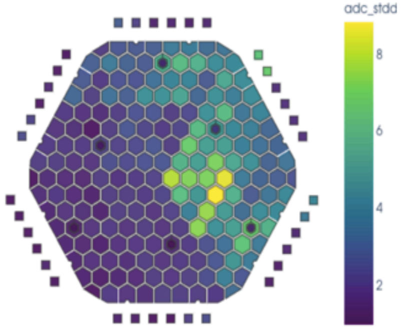
ML F3WXIH0015
F42MH00009



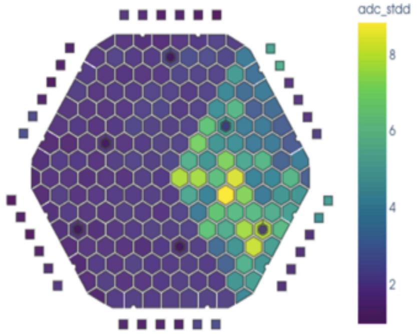
ML F3WXIH0016
F42MH00010



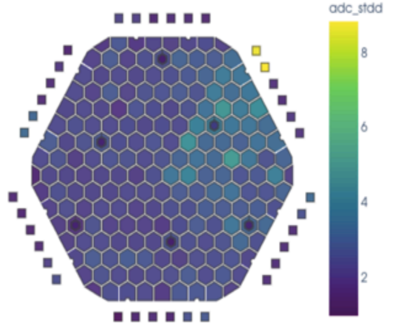
ML F3WXIH0017
F42MH00003



ML F3WXIH0018
F42MH00001

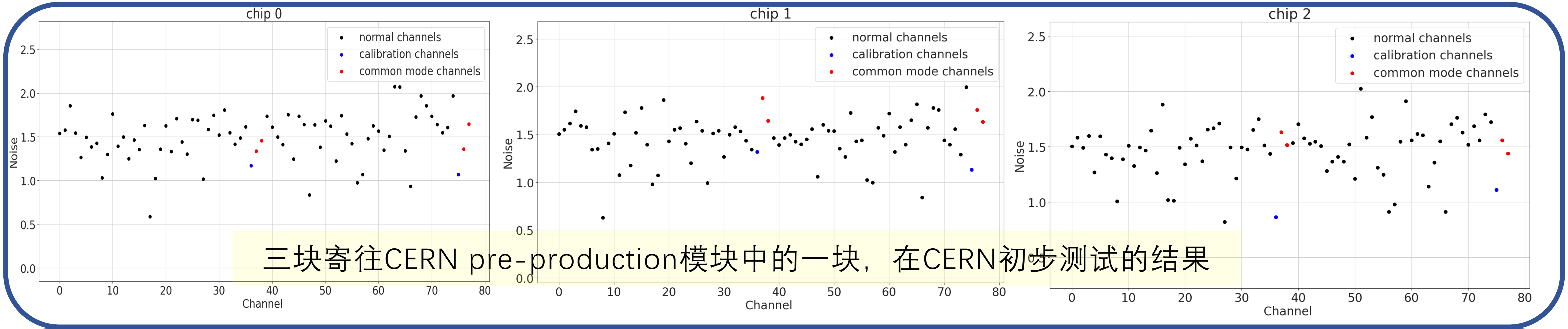


ML F3WXIH0019
F42MH00004

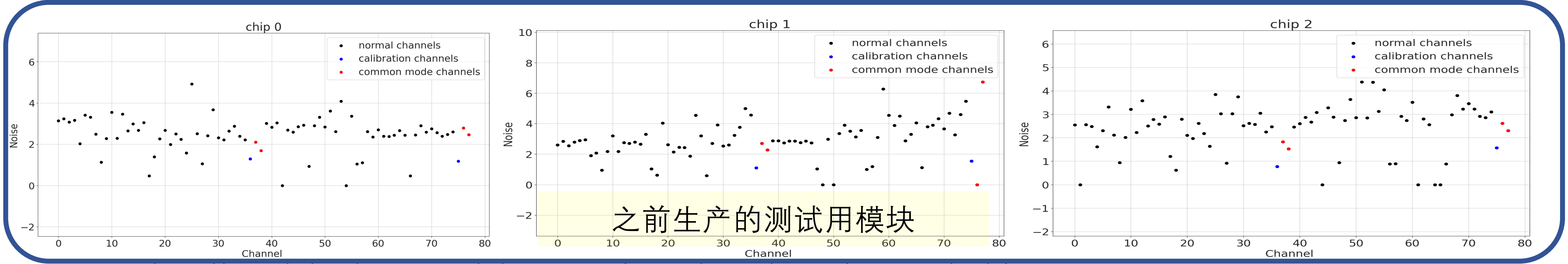


ML F3WXIH0020
F42MH00101

CMS-HGCal:电子学测试@CERN



三块寄往CERN pre-production模块中的一块，在CERN初步测试的结果



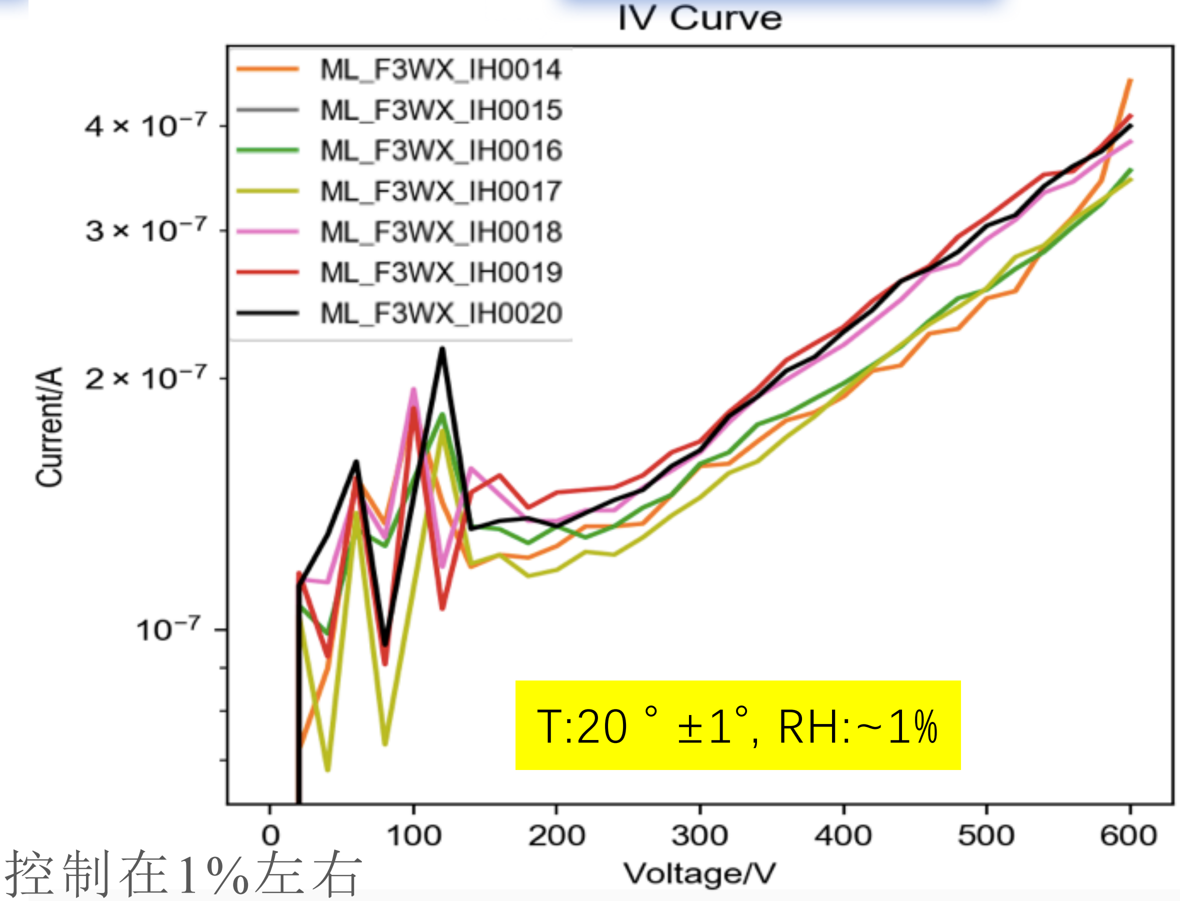
之前生产的测试用模块

- Arnaud：All modules have much better moise values than what you had in IHEP
- 高能所测到的噪声水平：2～10ADC，CERN测到的噪声水平（目前只拿到其中一块结果）：～1.5ADC
- 同时与之前制作的测试用模块（AISC不是最终版）相比，噪声水平由～3ADC降低到～1.5ADC。
- 后续CERN对高能所提供的3个模块进一步测试，以对ASIC的设计进行最终的验证。

CMS-HGCal: 电子学测试

Module assembly by gantry → Wire bonding → Encapsulation → **Electronic test @IHEP**

Module number	IV (No break down up to 600V)
ML_F3WX_IH_0014	√
ML_F3WX_IH_0015	√
ML_F3WX_IH_0016	√
ML_F3WX_IH_0017	√
ML_F3WX_IH_0018	√
ML_F3WX_IH_0019	√
ML_F3WX_IH_0020	√



T:20 ° ±1°, RH:~1%

- 我们利用高燥气体可将测试暗箱的相对是对控制在1%左右
- 模块整体漏电流在600V的偏压下小于1mA，并且没有发生明显击穿现象

总结及展望

□ ESD防护:

- 我们检查了洁净间、设备、人员等工作时的接地情况，结果显示接地良好。
- 检查了洁净间内所用物品是否满足防静电标准，并且按照防静电能力将不同类的物品进行归类，同时正在采购满足防静电要求的物品替代不满足要求的物品。
- 我们按照已发现的问题重新规范了模块组装及测试的操作规范，以提高模块良品率。

□ 模块生产:

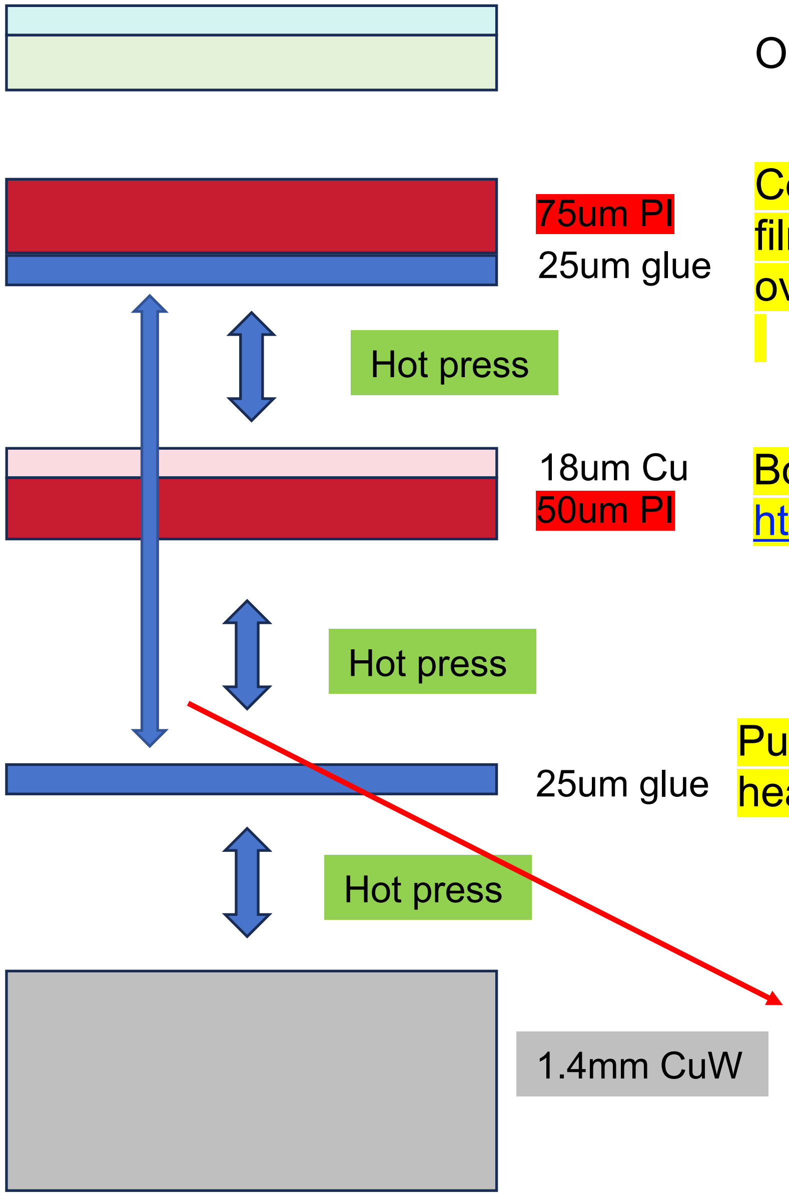
- 近一个月我们成功生产了7块HGCal模块。
- 其中3块已经寄往CERN。
- 模块的对齐精度和厚度控制满足要求。
- 初步电子学测试测试结果显示模块性能良好，所有通道均正常工作无坏道。通过CERN的初步反馈，这三个模块等电子学噪声表现良好。
- 在600V的偏压下面无明显击穿发生，同时模块整体漏电流小于1μA。
- 在已收到8块pre-producton的hexaboard中，在对最后一块进行切胶步骤后发现被击穿，怀疑是测试时击穿。我们并没有用它进行模块组装。

□ 计划

- 为即将到来的pre-series production进行准备工作。
- 将gantry的生产能力进一步提高，至少每天生产两个模块。
- 继续关注ESD问题，减少静电损伤。

Thanks

Process of bonding Kapton and CuW



Optional: 50 um 3M transfertape + protection paper for hybrid sensor gluing

Coverply: 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

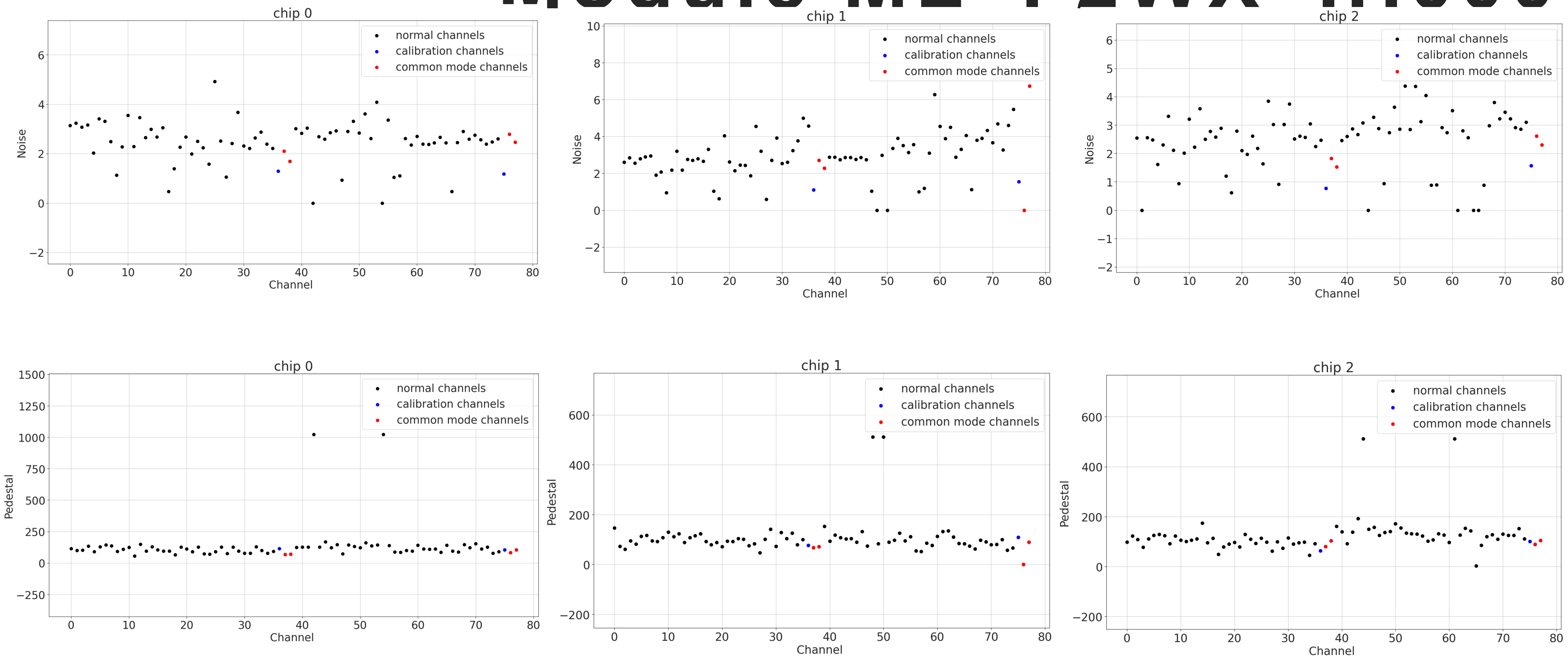
Bottom layer: Panasonic R-F777 (18 um Cu+50 um PI)
https://www.x-pcb.com/wp-content/uploads/R-F777-performance_www.x-pcb.com_.pdf

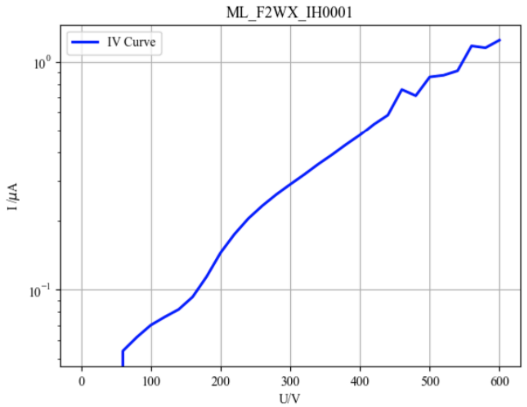
Pure adhesive: HaynerTaiXing Electronics HC25 (25um), epoxy adhesive, melts when heated.

Kapton and CuW are bonded together through a hot pressing process at a temperature of approximately 180℃.

We have produced 2 baseplates which use the epoxy adhesive （Hayner TaiXing Electronics HC25） for each layer of kapton and CuW baseplate lamination in hot press.

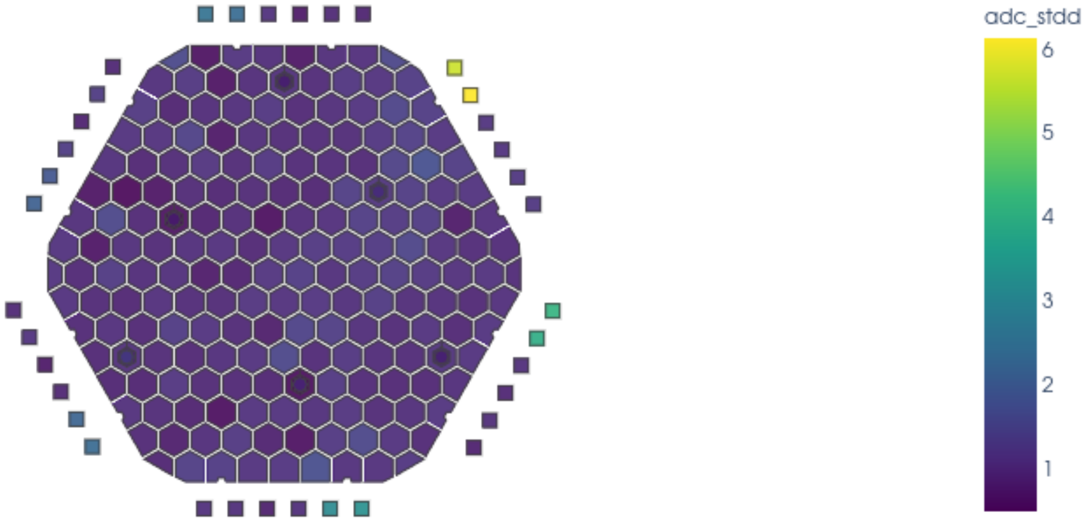
Module ML F2WX IH0001



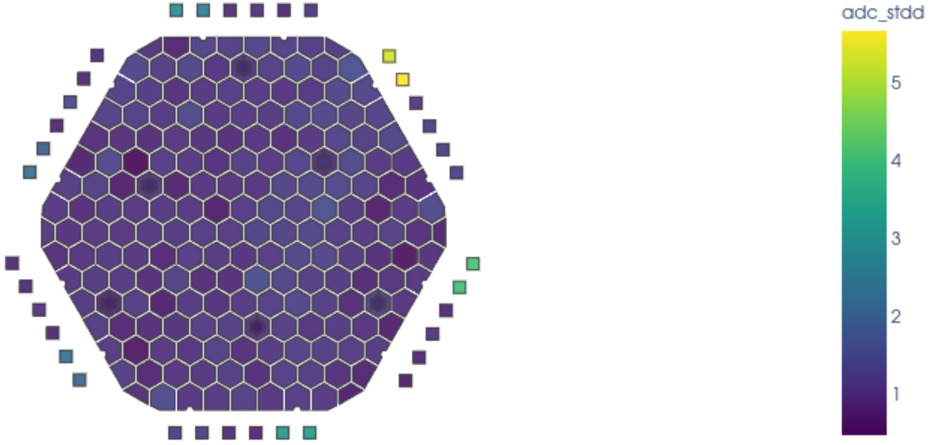


- The module test result is normal
- The module curve is normal

Test condition
temperature: 22 ℃
humidity: 0.1%
darkness

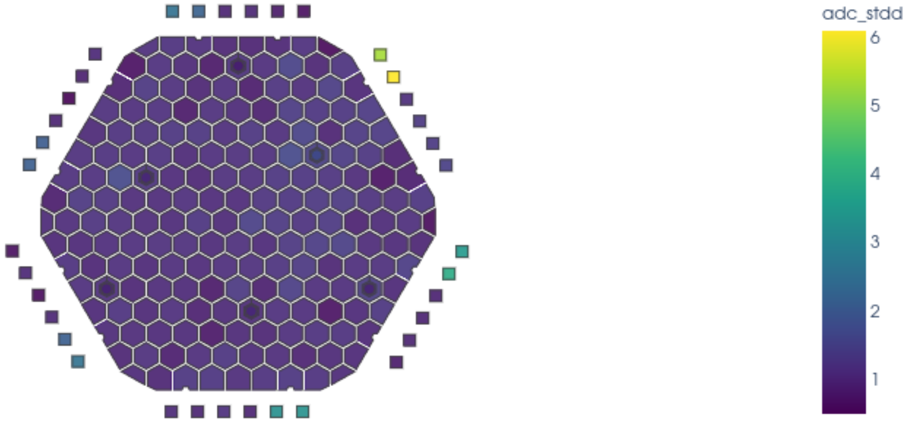


ML F3WXIH0014
F42MH00002



ML F3WXIH0018
F42MH00001

- Module noise test after assembly on gantry but before bonding



ML F3WXIH0019
F42MH00004