# ATLAS内径迹硅微条探测器升级进展和挑战

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On behalf of the ATLAS ITk China group

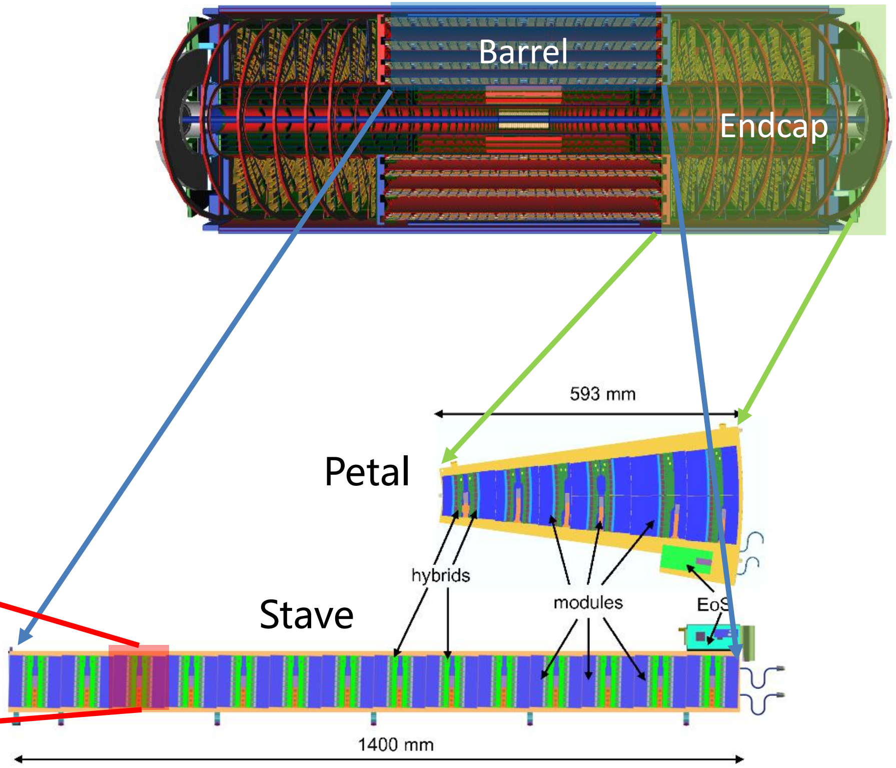
第六届半导体辐射探测器研讨会
上海，4月17日

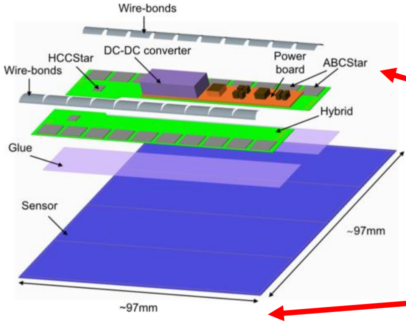
# 报告内容

- 项目背景和进展
- 中国组的贡献
- 挑战和解决
- 总结展望

# ATLAS内径迹探测器升级

- ATLAS ITk二期升级
  - 全硅探测器，长约6米，半径约1米
- 硅微条探测器
  - 4层桶部和6层(x2)端盖
  - 约18000个模块，约6千万道读出
  - 硅微条覆盖面积~165㎡
- 合作组
  - 16个资助机构，50个合作单位

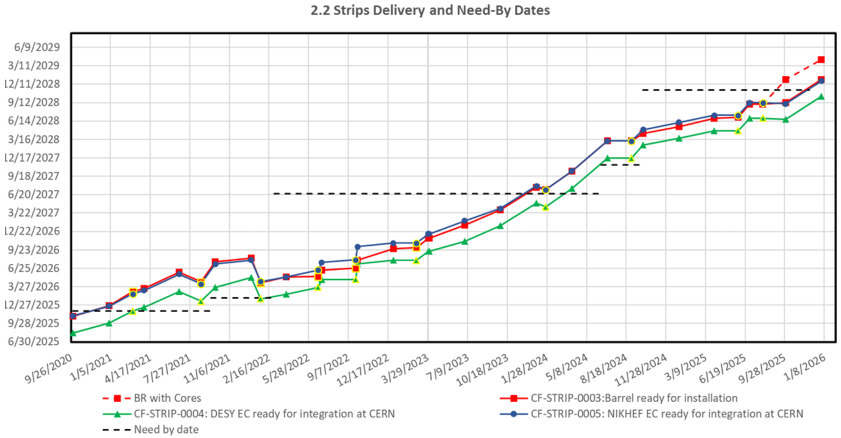


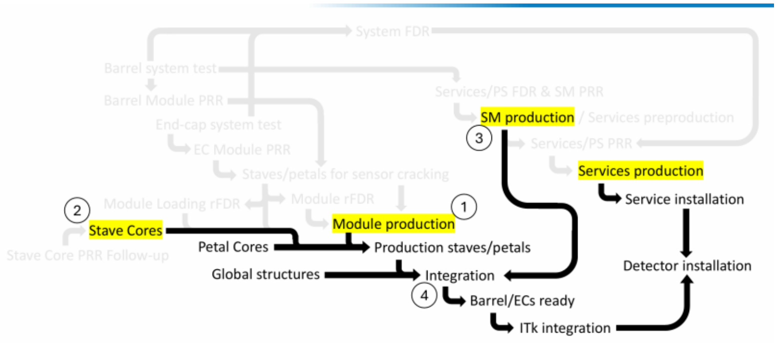


SS(Short Strip) module

# 项目进展

- 项目阶段
  - 样机->预生产->生产
  - 预计2028年夏结束模块生产
- 关键器件
  - 芯片生产已经结束
  - 传感器生产接近结束
- 生产流程简化
  - 样机阶段定义出质量控制（QC）的步骤和标准
  - 预生产阶段收集足够多的数据
  - 生产阶段简化流程，保证良率情况下提高生产率
- 集成和系统测试并行



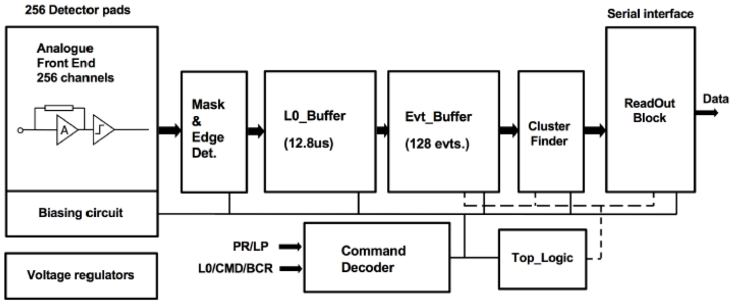


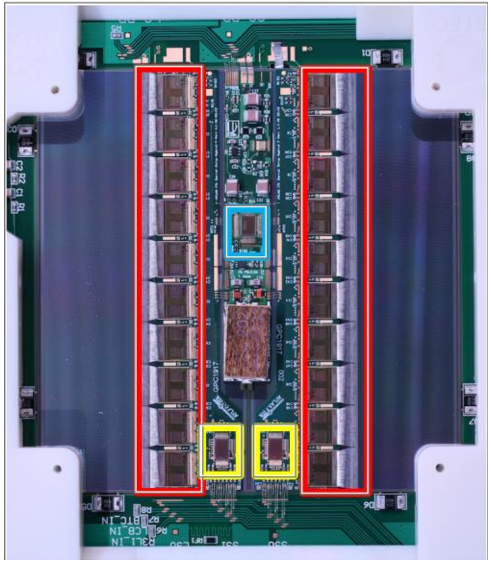
# 报告内容

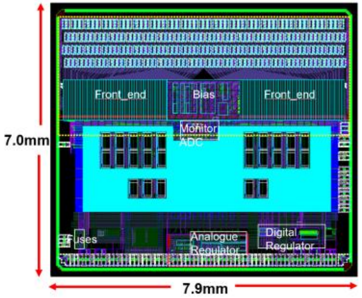
- 项目背景和进展
- 中国组的贡献
  - 芯片设计和测试
  - 传感器和芯片的辐照效应研究
  - 混合板和模块的生产研制
  - 模块束流测试和分析
  - 系统集成和测试
- 挑战和解决
- 总结展望

# 芯片设计和测试

- ABCStar, HCCStar, AMAC
- 参与前端读出芯片ABCStar设计和验证



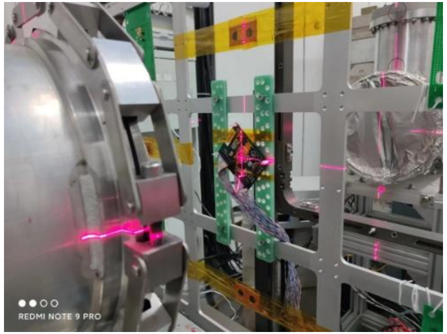




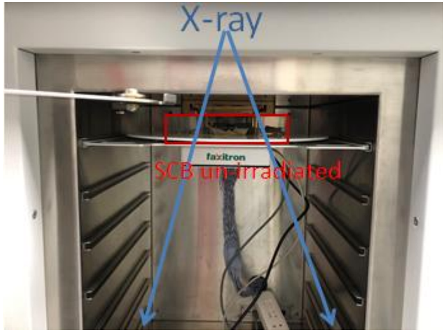
[Development of the ABCStar front-end chip for the ATLAS silicon strip upgrade]

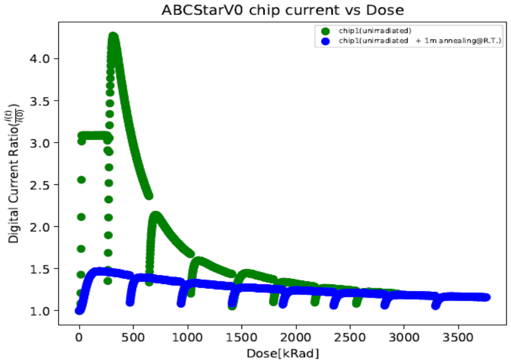
# 芯片辐照效应研究

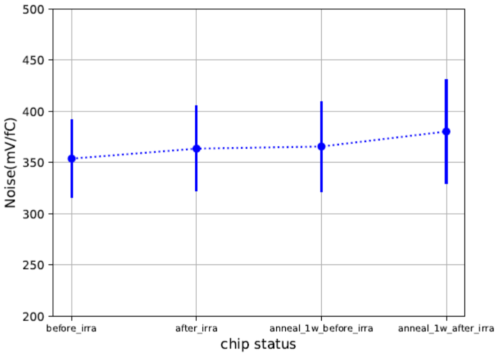
- 总剂量效应（TID）
  - X射线辐照
- 单粒子效应（SEE）
  - 80MeV质子
  - 单芯片和模块级芯片组

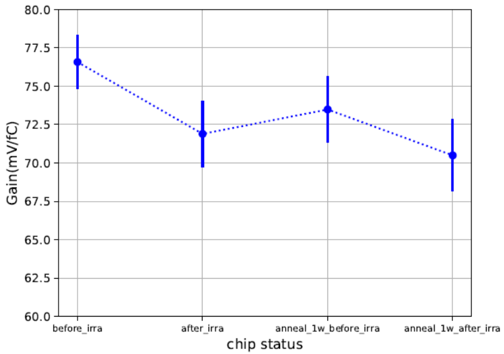


[Single event effect in ABC ASICs for ITk strip upgrade]



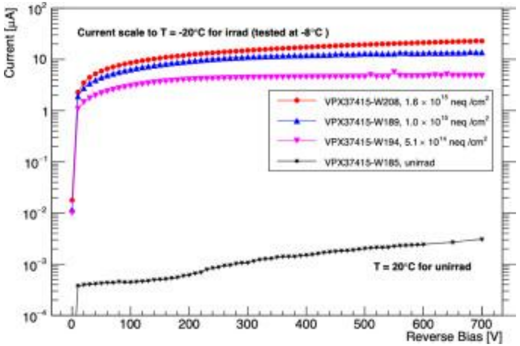


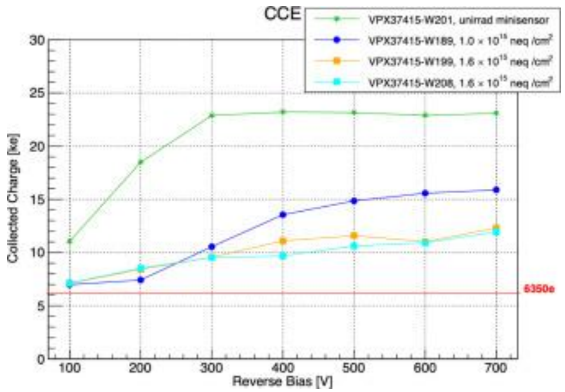




# 传感器辐照效应

- 传感器QA（Quality Assurance)
  - 传感器将被照射到比预期通量大50%的程度，以确保辐射耐受性不会恶化
  - 每个硅传感器晶片包含一个尺寸为1cmx1cm的微型探测器
  - 从交付的每批传感器中，将有少量微型探测器被照射到所需的通量
- I-V特性和C-V特性
- 电荷收集效率 (CCE)





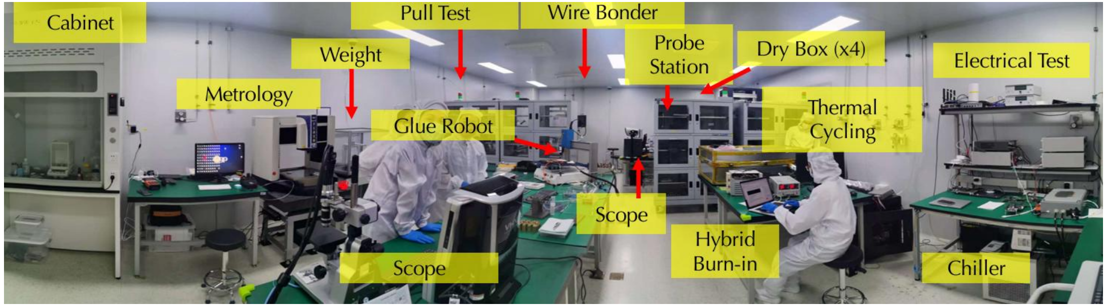
Feasibility study of CSNS as an ATLAS ITk sensor QA irradiation site

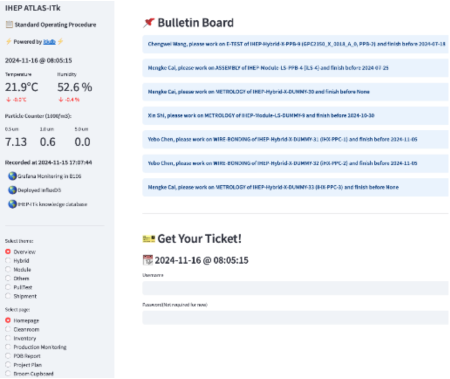
Irradiation study using QA test pieces of ATLAS18 ITk strip sensors with 80 MeV protons

# 生产站点

- 满足混合板和模块的生产
  - 建立了完备的洁净间实验环境
  - 通过站点评估
  - 建立标准操作流程及系统

| Poi | | Step Number | Qualification Step |
|---|---|---|---|
| Sensor Reception | TRUE | 3.2 | Sensor Storage |
| PB Reception | TRUE | 6.1 | PB Reception |
| | TRUE | 6.2 | PB E tests |
| | TRUE | 6.3 | PB Vis Insp |
| | TRUE | 6.4 | PB Storage |
| | TRUE | 8.2 | Storage + shipping of glue |
| | TRUE | 8.3 | Assembling hybrids |
| | TRUE | 8.4 | Glue weight measurements |
| | TRUE | 8.5 | Bonding procedures: hybrids |
| | TRUE | 8.6 | Metrology: hybrids |
| | TRUE | 8.7 | Visual inspection: hybrids |
| | TRUE | 8.8 | Hybrid Burn-In |
| | TRUE | 8.10 | Hybrid Storage |
| | TRUE | 8.11 | hybrid QC: single panel testing |
| Module Assembly/Testing | TRUE | 11.1 | Storage of modules |
| | TRUE | 11.2 | Cleaning module jigs |
| | TRUE | 11.4 | Storage + shipping of glue |
| | TRUE | 11.5 | Removing hybrids from panel |
| | TRUE | 11.6 | Module Assembly |
| | TRUE | 11.7 | Metrology: modules |
| | TRUE | 11.8 | Bonding procedures: modules |
| | TRUE | 11.9 | Visual inspection: modules |
| | TRUE | 11.10 | Module Thermal Cycling |
| | TRUE | 11.11 | Single Module Electrical Test |
| Module Shipping | TRUE | 12.1 | Shipping modules |
| General | TRUE | 13.1 | Cleanroom standards |
| | TRUE | 13.2 | ASIC Compliance & Handling |
| | TRUE | 13.3 | Bond Pulling Procedures |
| Module Reception | TRUE | 14.1 | Module Reception |





IHEP ATLAS-ITk

Standard Operating Procedure

⚡ Powered by Itkdb ⚡

2024-11-16 @ 08:05:15

Temperature: 21.9°C (↓ -0.0°C)

Humidity: 52.6 % (↓ -0.4 %)

Particle Counter (1000/m3):

0.5um: 7.13

1.0um: 0.6

5.0um: 0.0

Recorded at 2024-11-15 17:07:44

Grafana Monitoring in B106

Deployed influxDB

IHEP-ITk knowledge database

Select items:
● Overview
○ Hybrid
○ Module
○ Others
○ PullTest
○ Shipment

Select page:
● Homepage
○ Cleanroom
○ Inventory
○ Production Monitoring
○ PDB Report
○ Project Plan
○ Broom Cupboard

**Bulletin Board**

Chengwei Wang, please work on E-TEST of IHEP-Hybrid-X-PPB-9 (GPC2150_X_0018_A_0, PPB-2) and finish before 2024-07-18

Mengke Cai, please work on ASSEMBLY of IHEP Module LS-PPB-4 (LS-4) and finish before 2024-07-25

Mengke Cai, please work on METROLOGY of IHEP-Hybrid-X-DUMMY-30 and finish before None

Xin Shi, please work on METROLOGY of IHEP-Module-LS-DUMMY-9 and finish before 2024-10-30

Yebo Chen, please work on WIRE-BONDING of IHEP-Hybrid-X-DUMMY-31 (IHX-PPC-1) and finish before 2024-11-05

Yebo Chen, please work on WIRE-BONDING of IHEP-Hybrid-X-DUMMY-32 (IHX-PPC-2) and finish before 2024-11-05

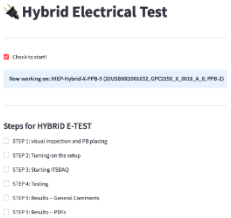
Mengke Cai, please work on METROLOGY of IHEP-Hybrid-X-DUMMY-33 (IHX-PPC-3) and finish before None

**Get Your Ticket!**

2024-11-16 @ 08:05:15

Username

Password(Not required for now)



**Hybrid Electrical Test**

☑ Check to start!

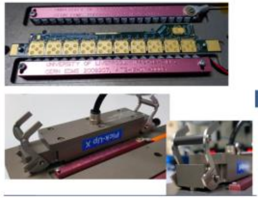
Now working on: IHEP-Hybrid-X-PPB-9 (20USBHX2001832, GPC2150_X_0018_A_0, PPB-2)

**Steps for HYBRID E-TEST**

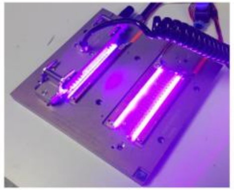
☐ STEP 1: visual inspection and PB placing
☐ STEP 2: Turning-on the setup
☐ STEP 3: Starting ITSDAQ
☐ STEP 4: Testing
☐ STEP 5: Results -- General Comments
☐ STEP 5: Results -- PDFs

# 混合板和模块研制

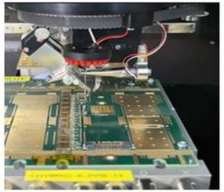
Pick up ASICs and alignment



Apply UV glue on hybrid and ASIC attachment



UV glue curing

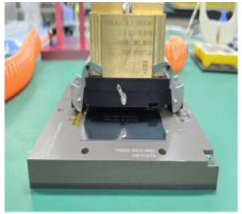


Wire bonding

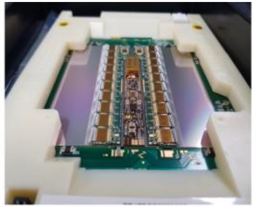
HBI

Dispense glue on stencil for hybrid

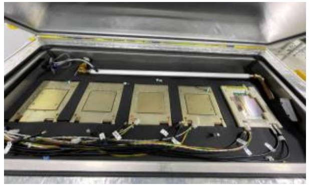
Dispense glue on stencil for PB



Glue curing for hybrid and PB

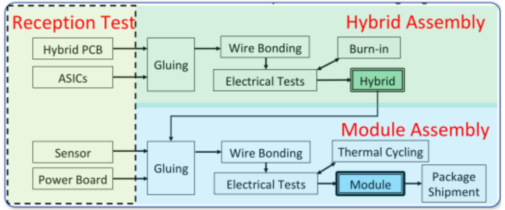


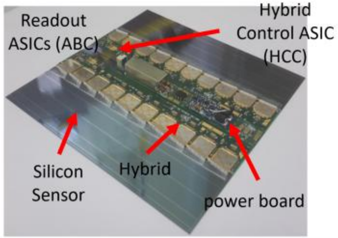
Wire bonding



MTC

- 高指标
  - 芯片胶厚：120+40/-60μm
  - 打线密度：256根线4层/cm
  - 漏电流：<~100nA@550V
  - 噪声：~800e





# 报告内容

- 项目背景和进展
- 中国组的贡献
- 挑战和解决
  - 模块冷噪声（cold noise）
  - 传感器碎裂
  - 模块EBD及恢复
  - bPOL的问题和解决
  - 静电问题
- 总结展望

# 模块冷噪声

- 模块在热循环至低温（-35℃）部分通道噪声变大
- 电源板上的电容震动通过传感器传播引起噪声
- 通过调整胶水类型和粘胶方法可以解决
- 解决办法在辐照和磁场下仍然适用

Cold noise investigation

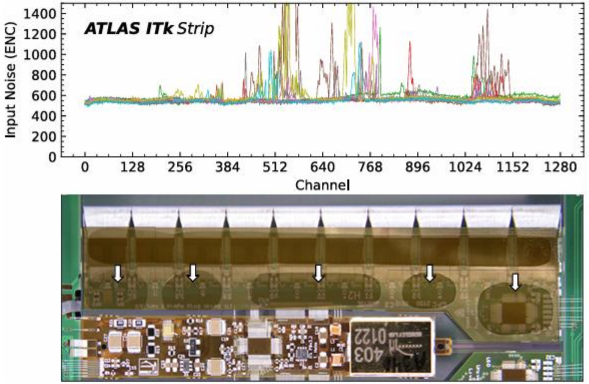


**Figure 2.** Input noise of 10 modules tested at -35°C. The locations of strips exhibiting Cold Noise tend to coincide with the hybrid glue lines closest to the power-board (white arrows).

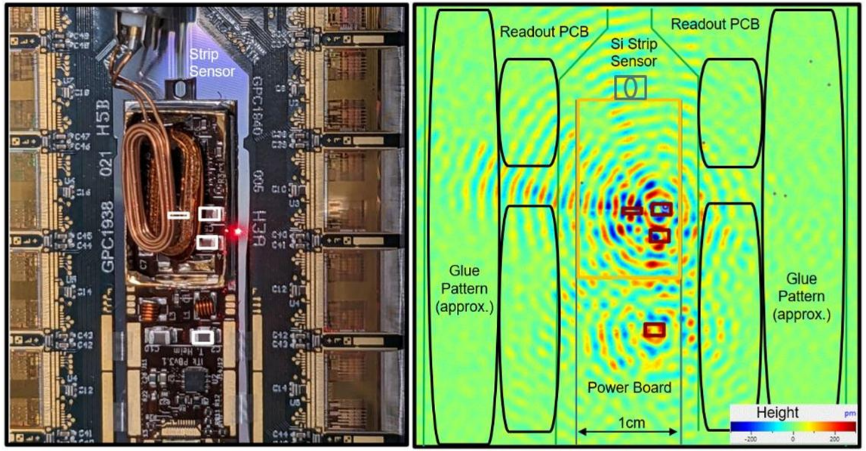
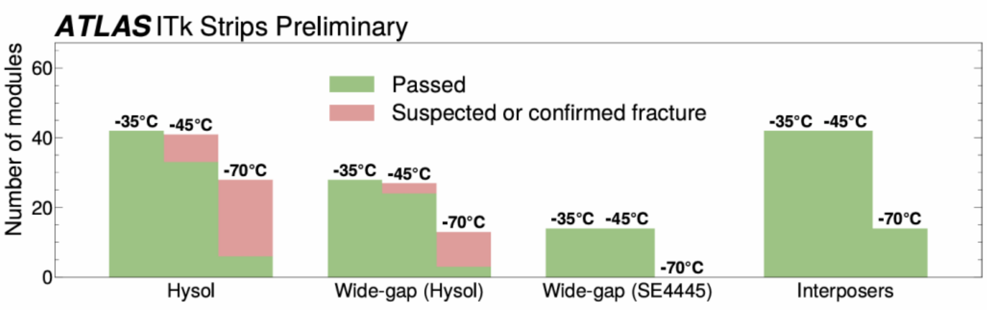
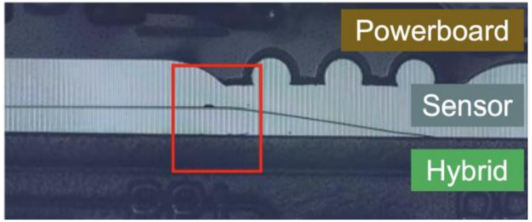


**Figure 5.** On the left is a photo of a silicon strip module with the four 11 V capacitors in the buck converter pi filter outlined. On the right is a vibrometer scan showing the mechanical wave passing through the silicon sensor with the components of the module overlaid.

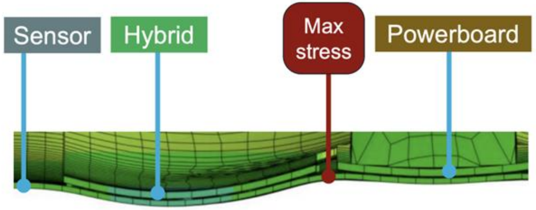
# 传感器碎裂

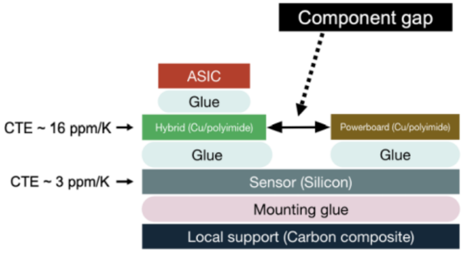
- 桶板热循环测试中部分模块碎裂
- 混合板跟传感器的热膨胀系数（CTE)不同
- 缓解方法
  - 模块和桶板之间改用Hysol胶水
  - 增大电路板之间的间隙
  - 电路板和传感器之间用垫片机械隔离

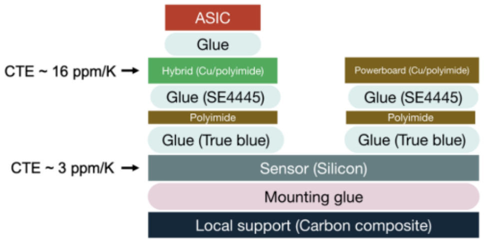




[Mitigation strategies for sensor fracturing in the ATLAS ITk strips detector]()

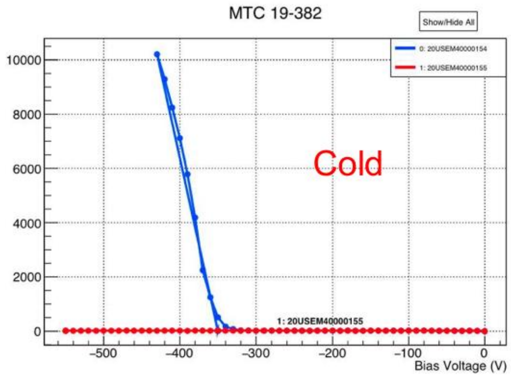


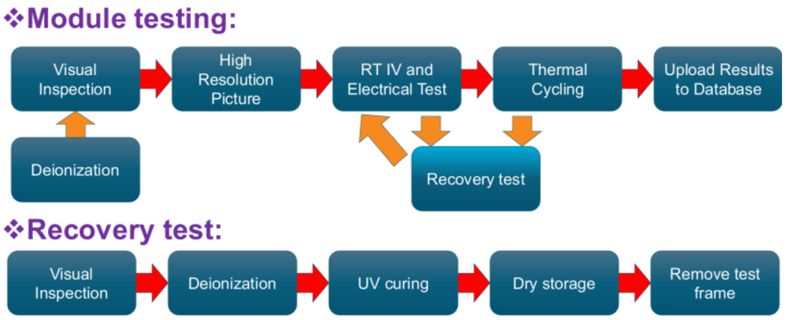




# 模块EBD和修复

- EBD（Early Break Down），传感器在未达到正常工作电压情况下漏电流显著增大
- 在各个生产站点都有发生，且比例较高
- 探索多种修复方法的效果和效率
- 建立标准修复流程





❖Module testing:

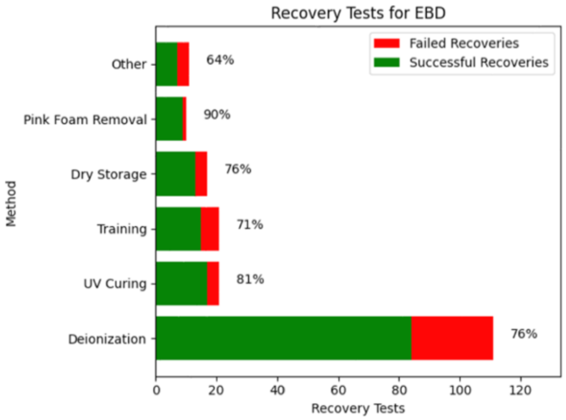
Visual Inspection → High Resolution Picture → RT IV and Electrical Test → Thermal Cycling → Upload Results to Database

Deionization

Recovery test

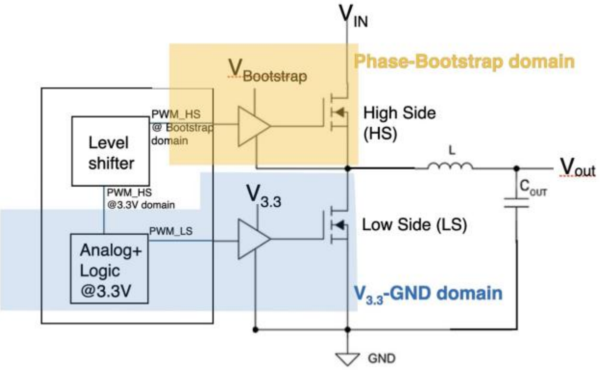
❖Recovery test:

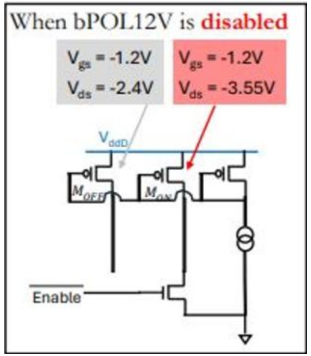
Visual Inspection → Deionization → UV curing → Dry storage → Remove test frame



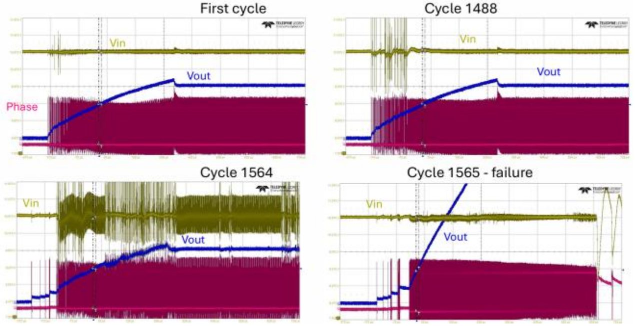
# bPOL问题

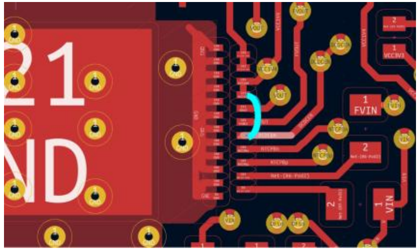
- bPOL12V芯片是电源板上的一个DCDC电源
- 在低温，辐照和电源频繁开闭使用情况下失效
- ITk修改电源板
  - 硬连接使能
  - 最简洁的缓解失效的方法
  - 测试数据显示能满足实验生命周期的需要

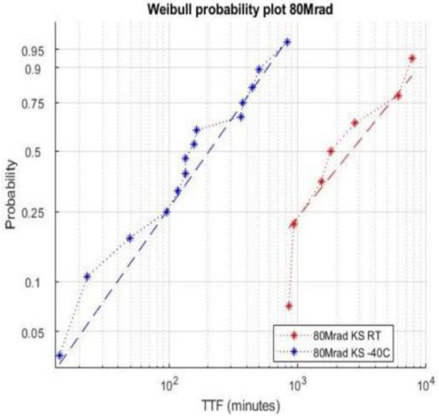




Example of a bPOL12V irradiated with X-rays up to 70Mrad and enable cycled at -30C







# 总结与展望

- ATLAS内径迹硅微条探测器升级已经正式进入生产阶段，预计两年内完成生产
- 中国组在芯片设计、关键器件辐照效应研究，混合板和模块生产方面做出了重要贡献
- 合作组在项目实施过程中解决了遇到的多个工程技术难题
- 尽早开展完备的测试，及时发现设计中的缺陷，避免影响工程进度

欢迎批评指正