ATLAS 实验硅微条径迹探测器升级

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参加单位：中科院高能物理研究所、清华大学

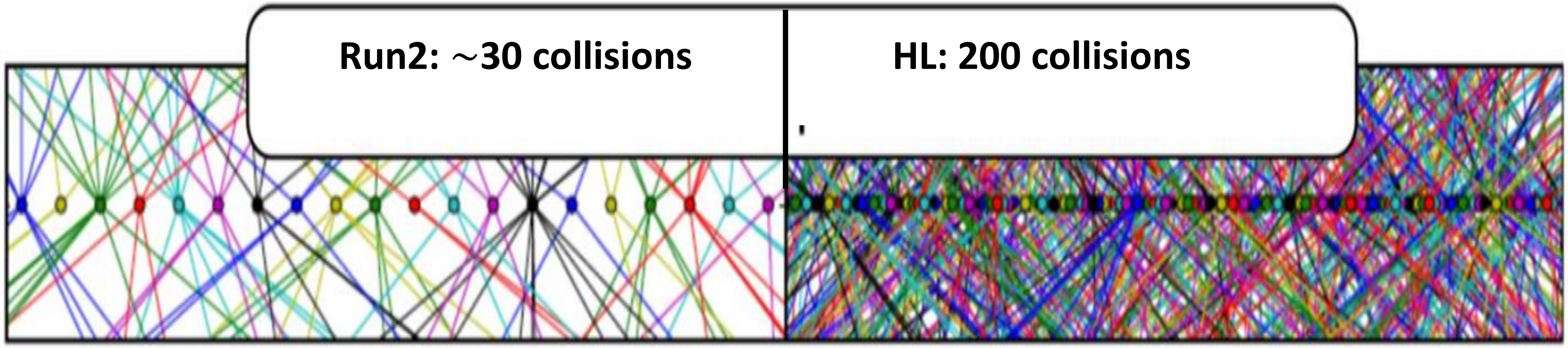
LHC探测器升级研讨会，2020.8.11-12

报告提纲

- 项目介绍
- 子课题研究进展
  - 前端电子学
  - 硅微条探测器模块性能研究及建造
  - CMOS硅微条探测器性能研究
- 总结及展望

ATLAS径迹探测器升级

- 大型强子对撞机将从2026年开始以高亮度模式运行。
- ATLAS探测器全面升级，以应对高计数、强辐照的运行环境。



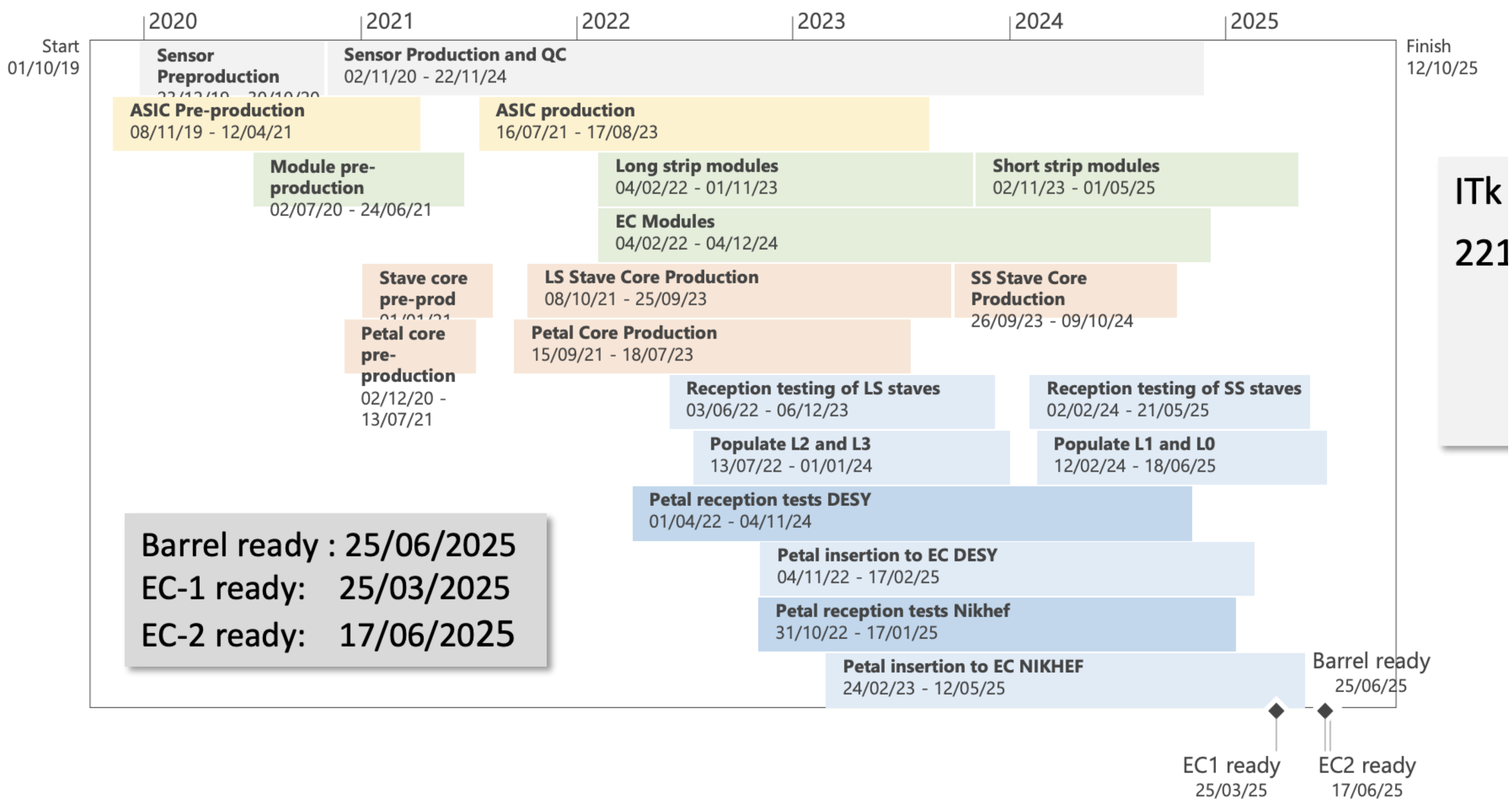
- ✦ 高能所+清华承担硅微条探测器升级任务
  - 目标研制抗辐照、高分辨、快读出且低物质量的硅微条探测器
  - 完成1000个硅微条模块（$10m^2$硅）并集成到ATLAS探测器
- ✦ 国内首次在ATLAS实验承担大面积抗强辐照径迹探测器建造任务，并参与安装点的系统集成与联调工作。
- ✦ 系统掌握**建造抗辐照硅探测器**的关键工艺流程，获得**硅探测器系统设计、集成及调试**相关的关键技术，为以后自主设计此类复杂硅探测器系统奠定坚实基础。

本年度计划（任务书内容）

2019 年 7 月 | 2020 年 6 月	硅微条探测器模块预生产；	√ 硅微条探测器模块空间分辨率：25 微米，抗辐照性能：1.6×10^{15} 1MeV n_{eq}/cm^2	√ 硅微条探测器模块工程样机
2020 年 7 月 | 2021 年 6 月	硅微条探测器模块批量生产	硅微条探测器模块达到合作组探测器升级项目指标要求	至少 50 个可工作的硅微条探测器模块

- 预生产/批量生产的预期目标（50个探测器模块）维持不变。
- 受疫情影响，开始时间略有延迟。

ATLAS 硅径迹探测器升级时间表（更新）

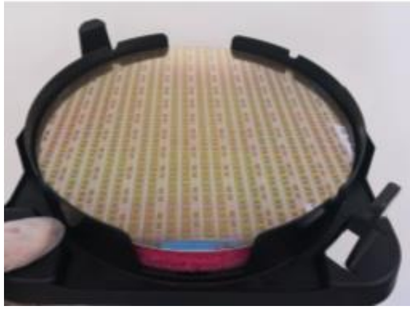


- **硅微条探测器模块预生产**（PRE-PRODUCTION）从2020年第三季度开始，持续1年时间，将完成模块批量生产总量的5%。
- **硅微条探测器(桶部+端盖)** 计划于2025年8月底完成系统测试，等待与硅像素探测器总装及后续安装调试

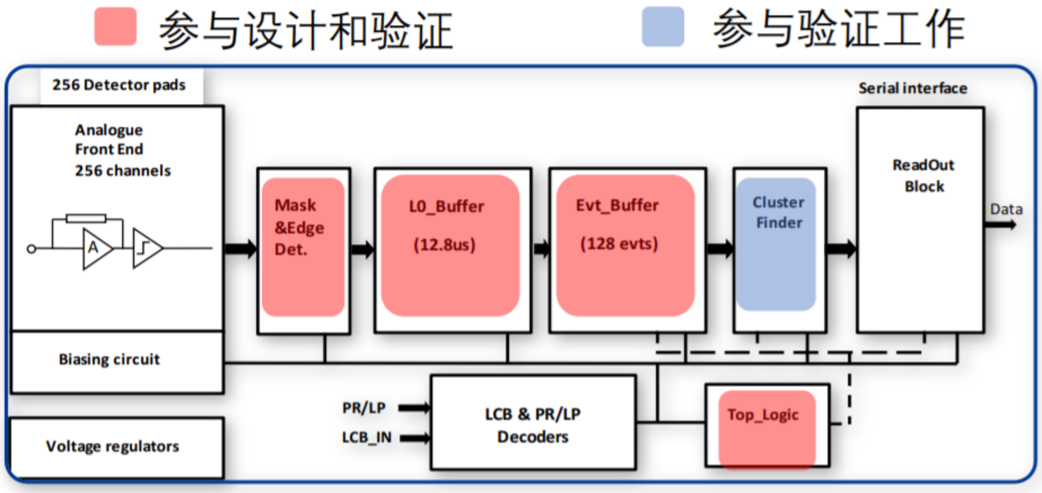
课题一：前端电子学

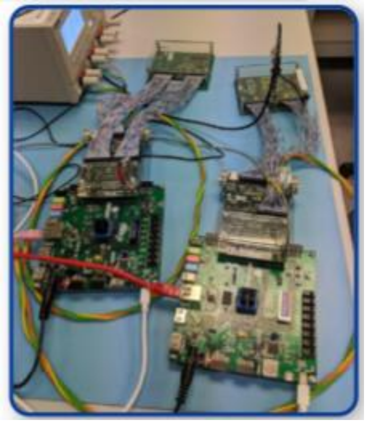
参与高数据传输率、抗强辐照ASIC芯片设计

科技部任务书



- ATLAS径迹探测器硬件触发率提升，前端读出ASIC芯片重新设计以适应全新的数据流架构—ABC-STAR芯片
- 高能所参与芯片数字部分设计及验证工作

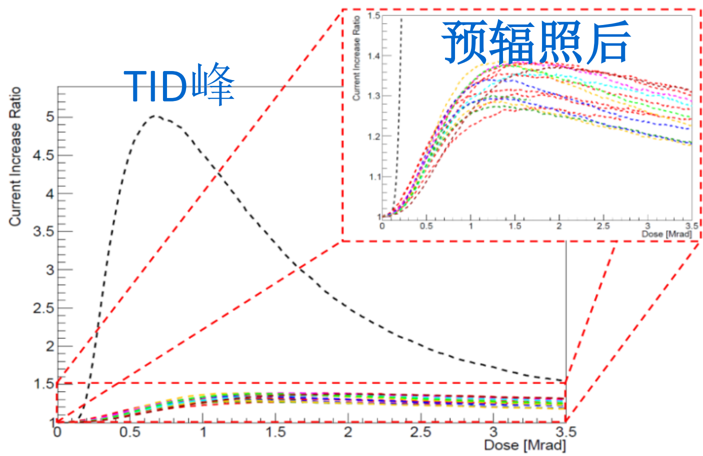




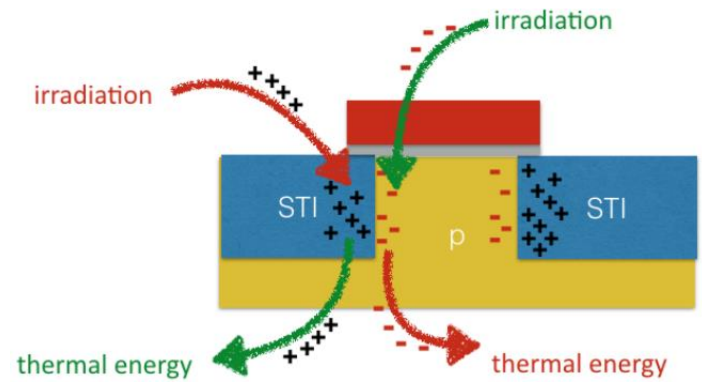
- 芯片用于探测器模块原型样机建造，已经过验证。联调通过，课题完成。
- **拓展性研究:**强化抗辐照研究能力，为将来抗辐照加固设计提供参考。
  - 总辐照剂量（TID）
  - 单粒子效应

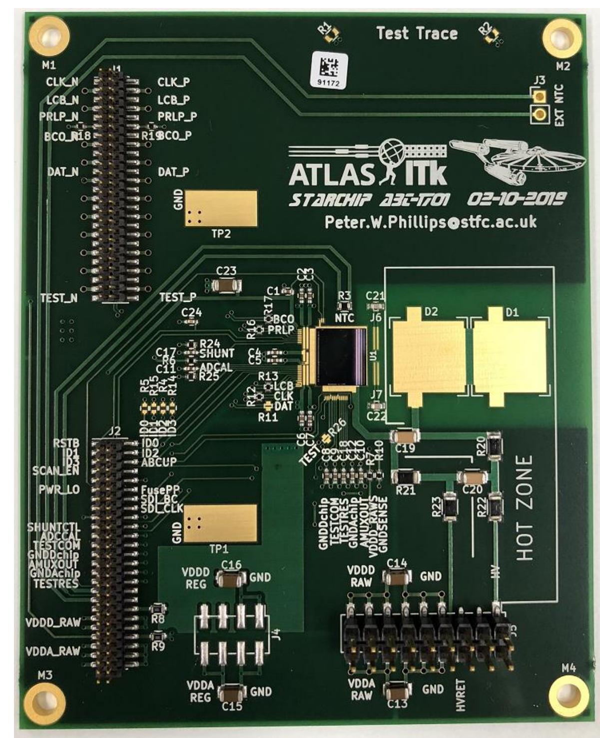
芯片预辐照

- 芯片经受辐射，由于TID效应，工作电流增大
  - 漏电流取决于“辐照产生陷阱捕获电荷”及“热激发退火”两种效应
  - 强依赖于环境（辐射剂量率、温度），很难预测实际应用中的漏电流



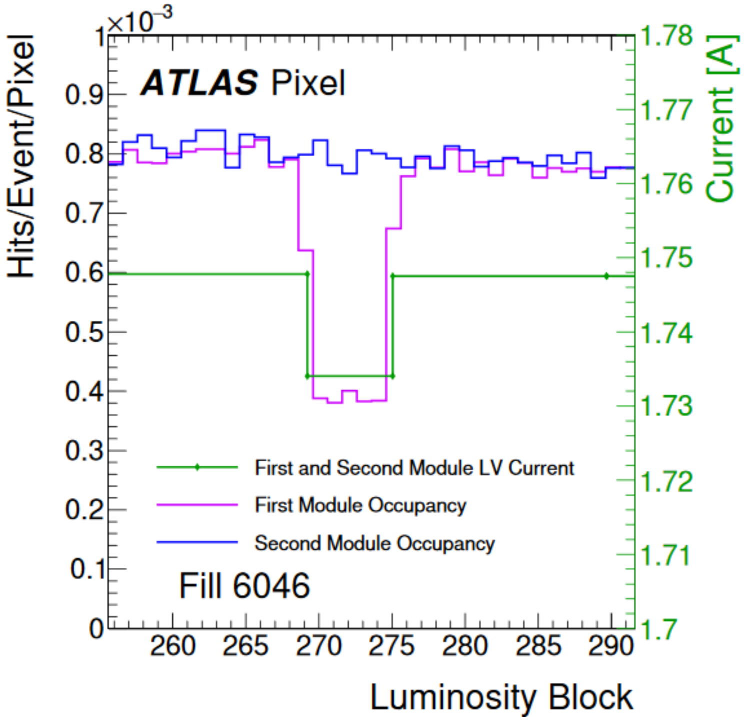
- 模块(预)生产将采用预辐照后的芯片，避开TID峰
- 收到TID测试版，检验辐照前后的TID峰

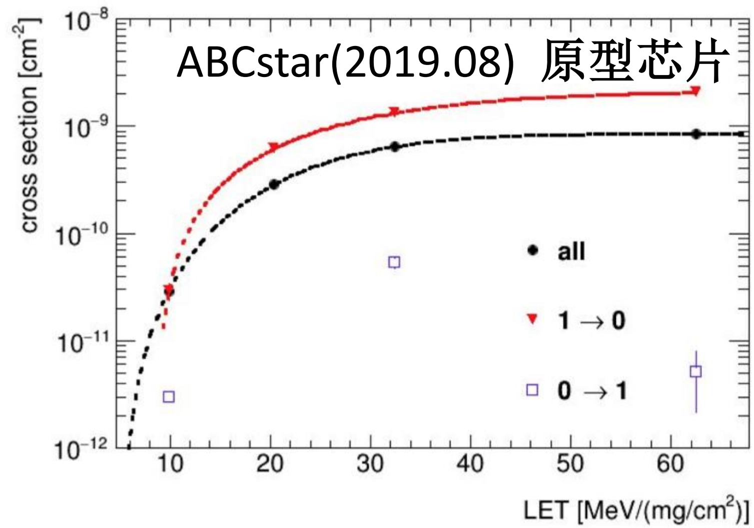




单粒子效应（SEE）

- 单个高能粒子击中器件灵敏区，通过电离作用产生额外电荷改变其逻辑状态（SEU），甚至单粒子瞬态脉冲作用到数据寄存器导致多个逻辑单元同时发生状态异常（SET）。





- 预生产用的ABCStar流片已返回，正在TRUMF及Louvain进行SEE测试。
- 受疫情影响，委托设施单位进行现场测试。后期分析数据，定量测量单粒子效应的截面。

课题二：硅微条探测器模块性能研究及建造

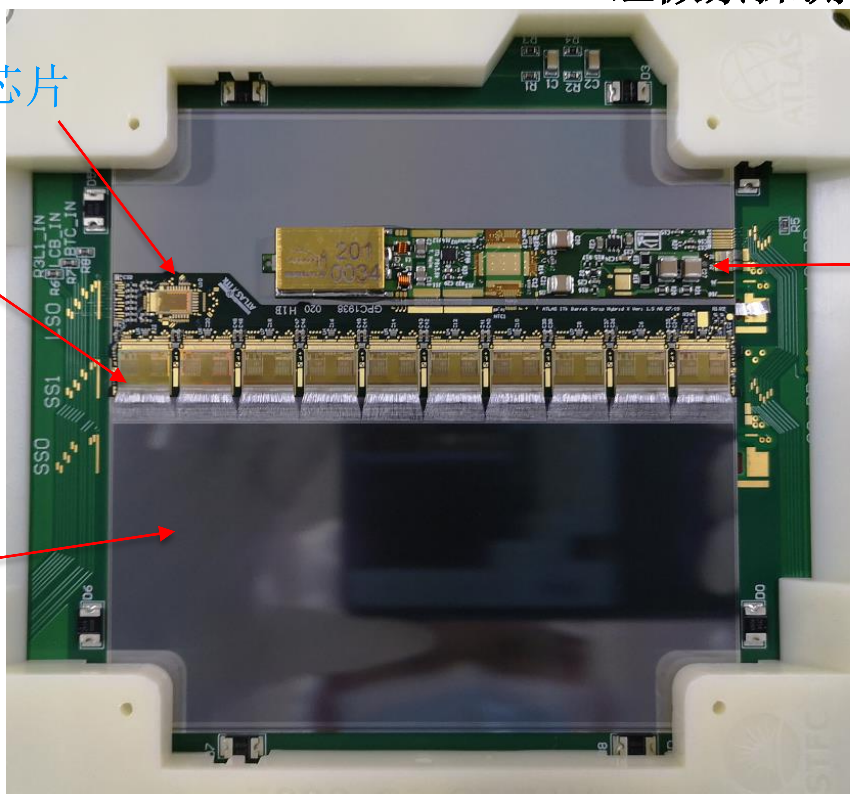
系统掌握建造抗辐照硅探测器的关键工艺流程

获得硅探测器系统设计、集成及调试相关的关键技术

硅微条探测器模块

- **承担1000个模块的建造与测试任务**
- 最基本机械单元，由硅微条传感器、复合PCB控制板（读出ASIC芯片+控制芯片）、电源板等构成，使用银胶或紫外凝胶粘合，打线实现电气连接
- 芯片组两个版本：130，**STAR(正式生产用)**

硅微条探测器模块及主要组件

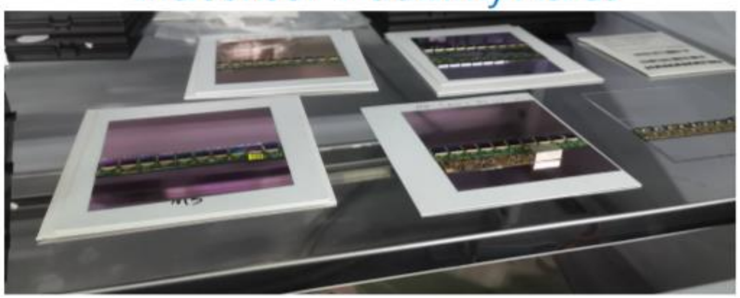


主要进展：硅微条探测器模块

- 已经收尾130原型模块制造。
- 进阶到STAR原型样机，完成两个STAR模块。按照完整的质量控制程序制作，并完成测试。

130 探测器模块

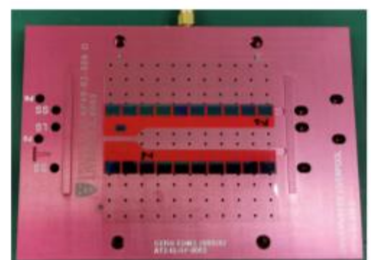
MS sensor + dummy ASICs

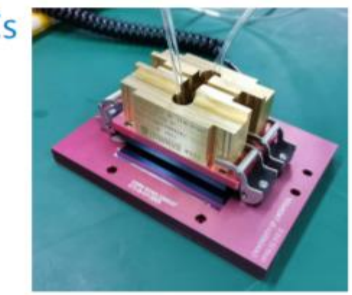


17LS sensor + 130 ASICs

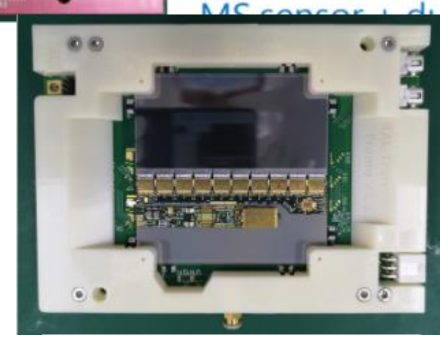
STAR 探测器模块

Glass sensor + dummy ASICs





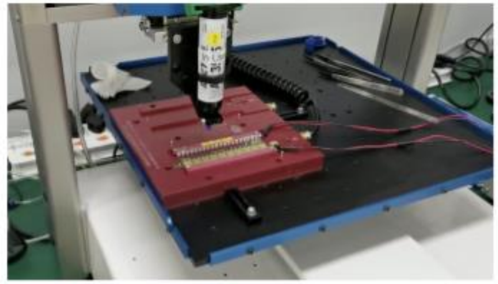
MS sensor + dummy ASICs



STAR hybrid + ASICs

STAR 模块制作 I

Hybrid 制作主要步骤：



平整度检查

柔性PCB（+无源器件）

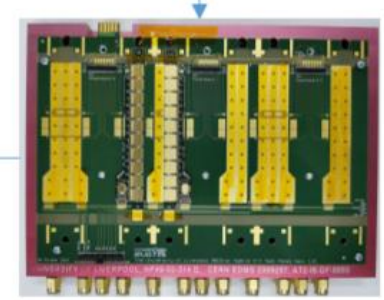
1. 自动点胶　2. 紫外凝固　3. 胶水厚度等测量　4. 后端打线

Hybrid

工装夹具加载（位置、间隙控制）

ABC/HCC芯片

5. 电子学测试（**生产阶段需长时间烘烤**）

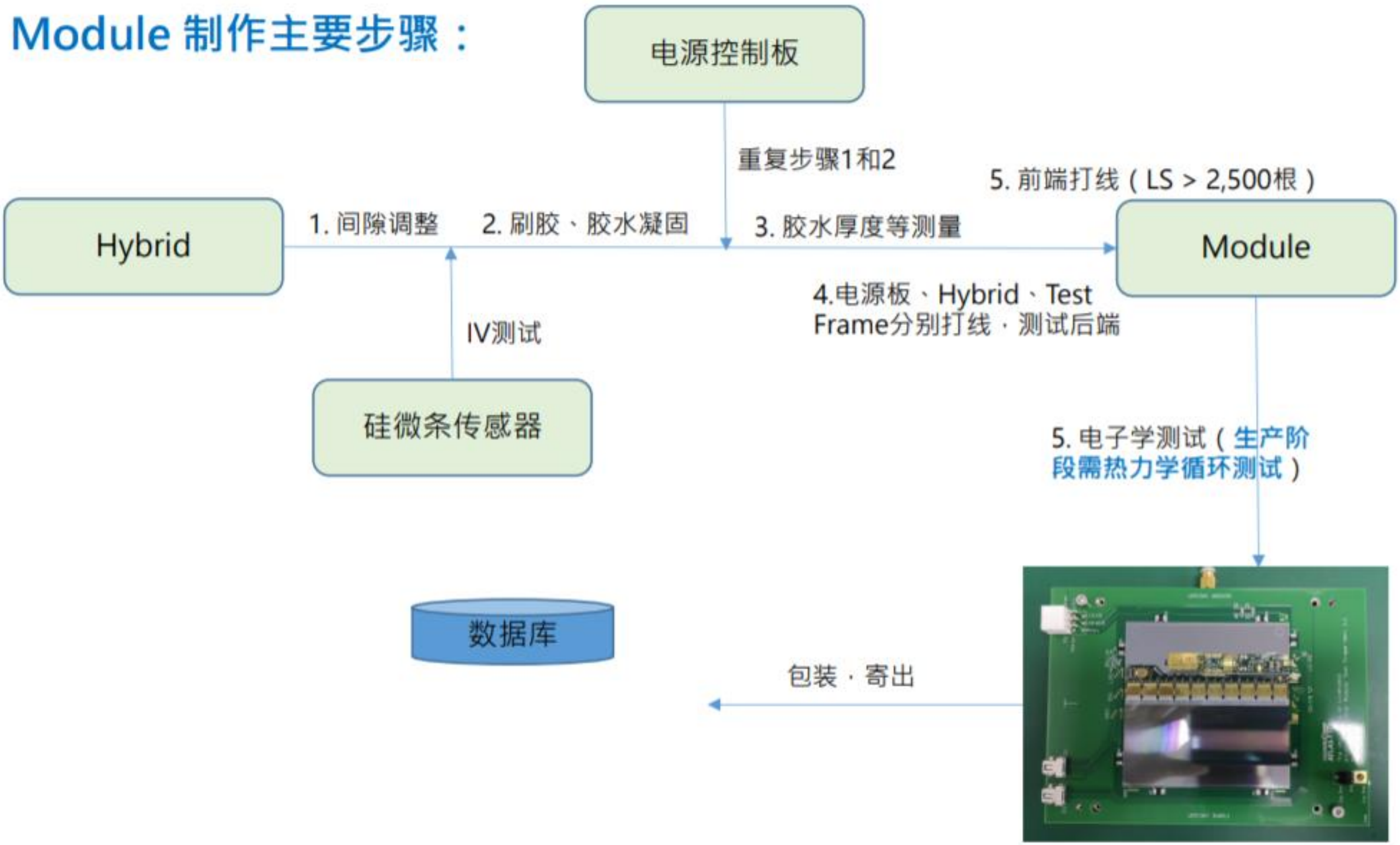


用于模块制作

数据库

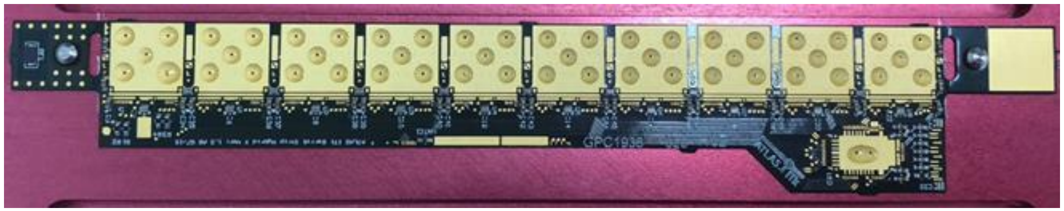
STAR 模块制作 II

Module 制作主要步骤：

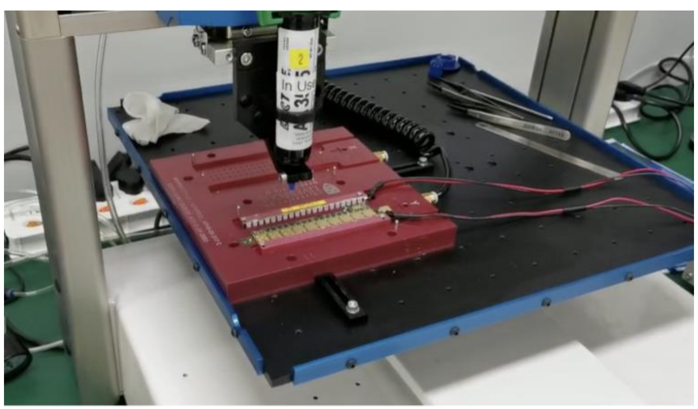


高精度点胶

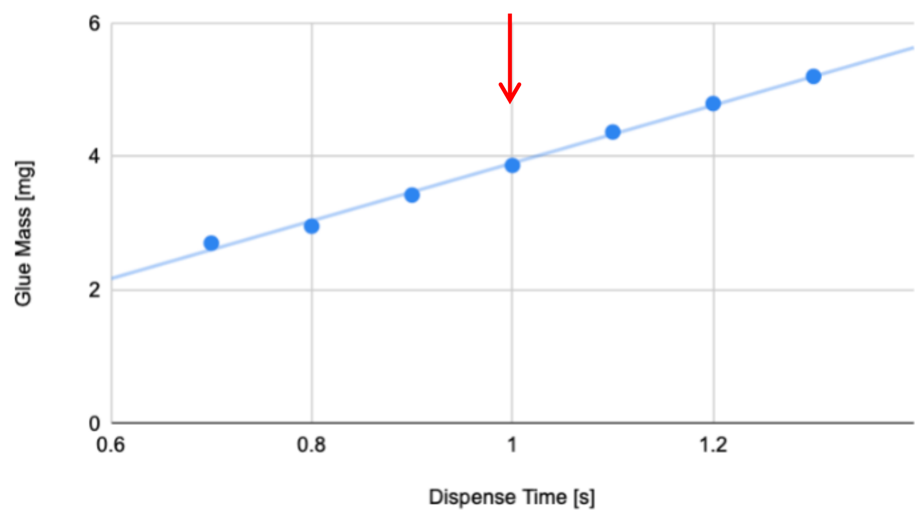
- 胶水的厚度和重量都有明确要求，比如ABC芯片与hybrid之间胶水重量4.05±0.25 mg → **散热、支撑、机械精度、是否适于打线**等综合考虑



- 自动点胶机

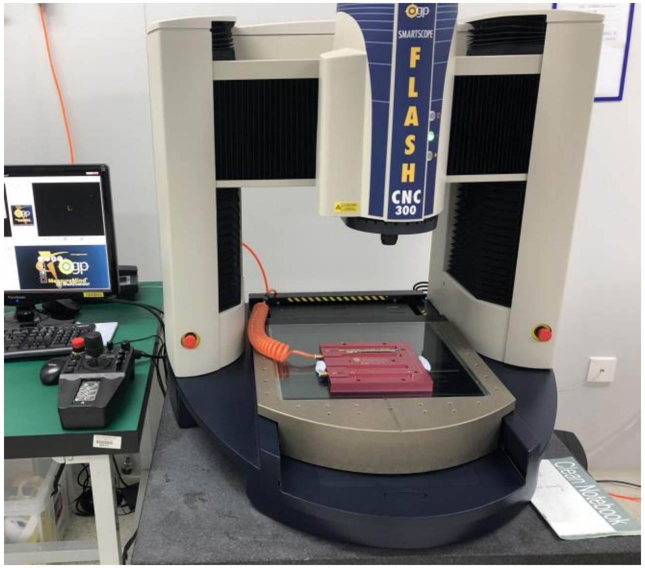


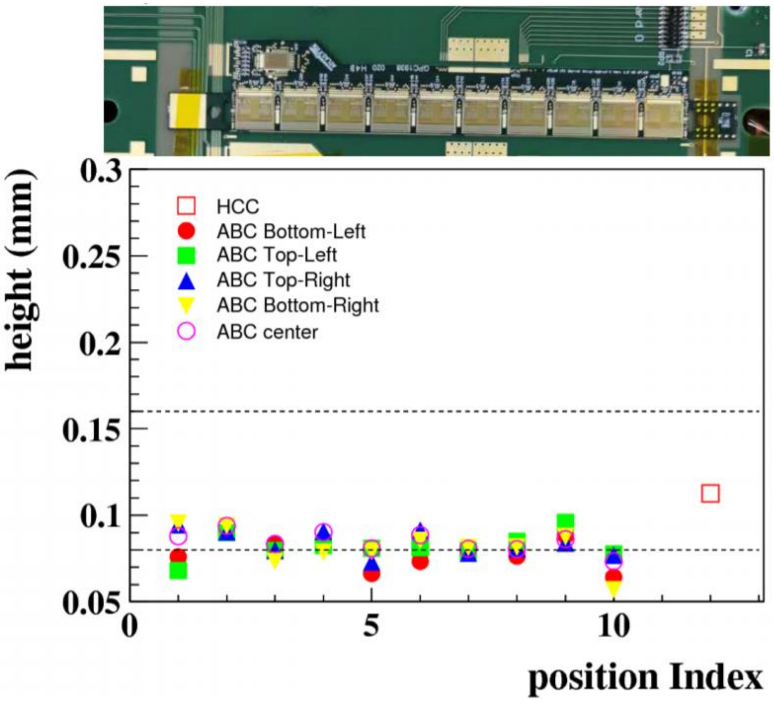
- **刻度胶量~喷胶时间**
- 材质、温度依赖

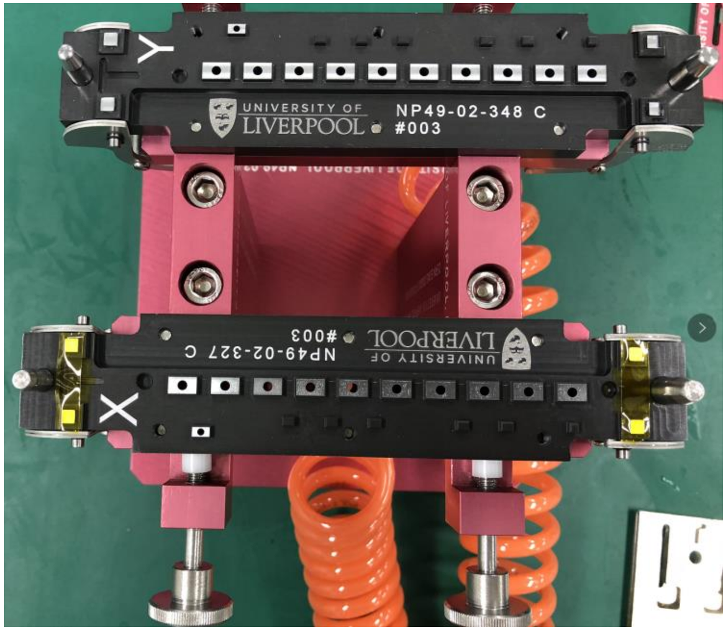


胶水厚度等测量

- 胶水的厚度靠组装工具控制
- 使用影像仪（SmartScope）激光扫描测量得到芯片与hybrid PCB之间胶水的厚度、hybrid与传感器之间的厚度等等
- **为正式生产做准备，完善质量控制**

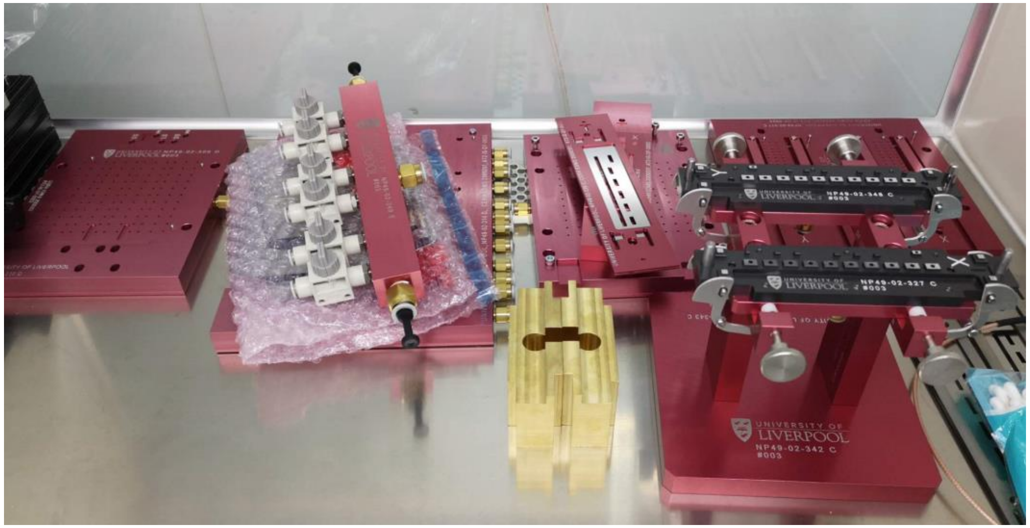




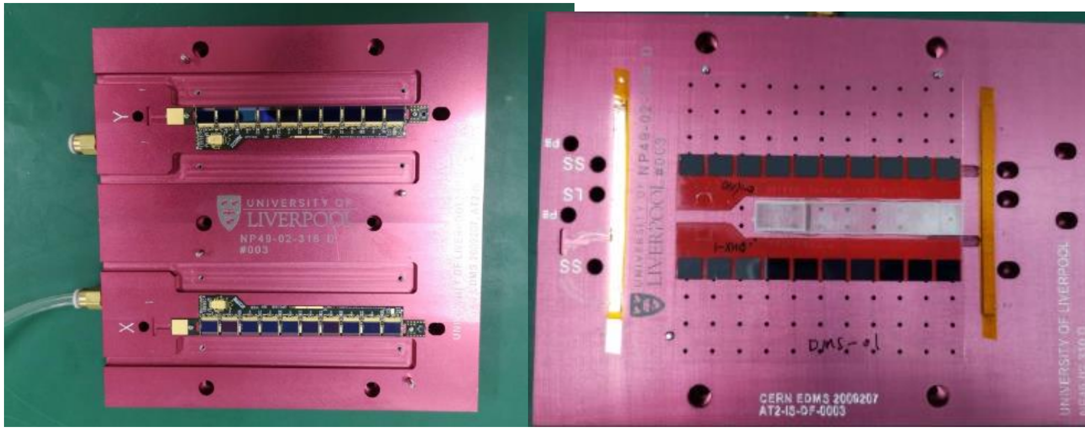


提高成品率

- 提高工艺水平，保证生产阶段的成品率
  - 器件本身质量，工具设计，人为操作



- 原型模块建造阶段反复练习
  - 利用无源器件**进行练习，验证工具及方案**
  - 胶的厚度及质量、组分部件的**定位精度**



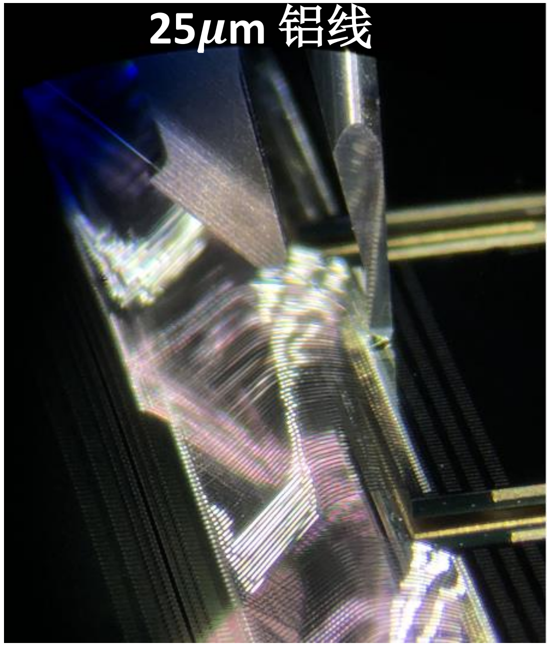
线绑定

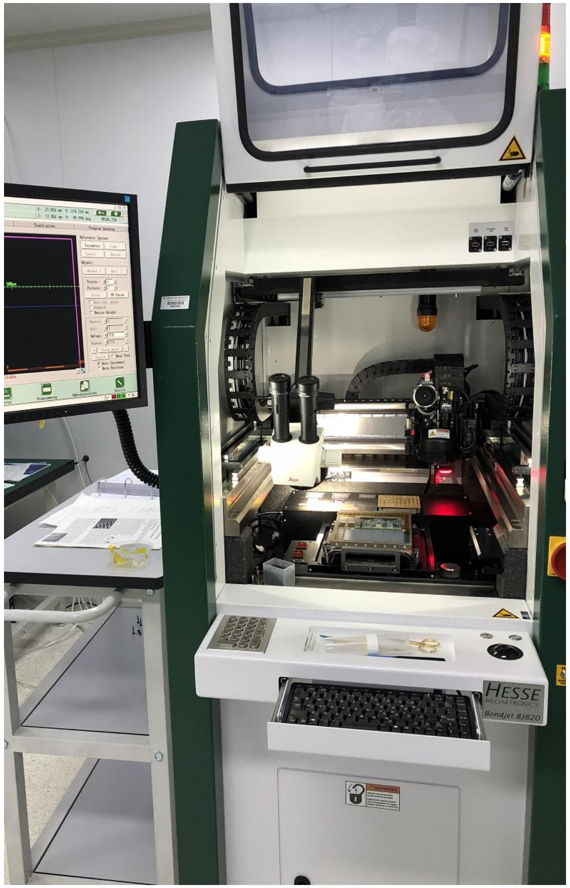
- 探测器模块打线总数（SS>5,000 LS>2,500），需要仪器长时间稳定运行

  熟练运行程序，修复坏线

- 芯片与传感器之间四层高密度引线

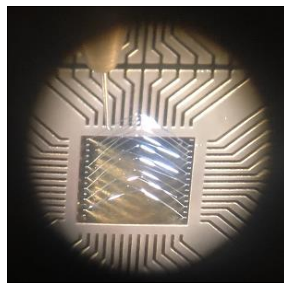
- 机器运行在20%全速，权衡故障率及宕机维修时间成本。

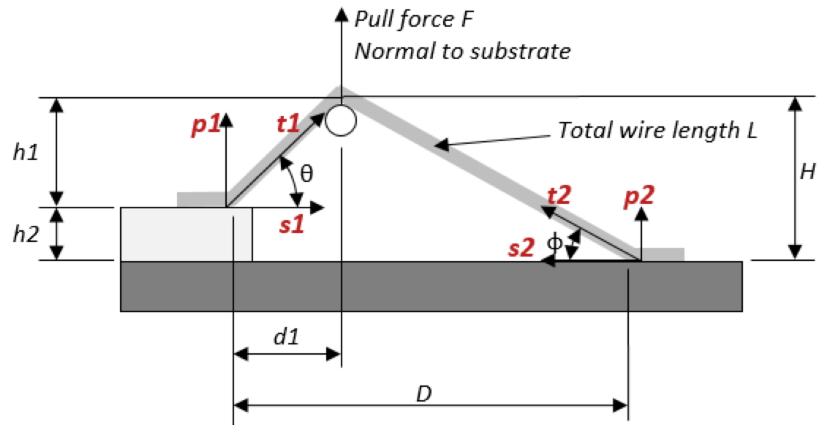




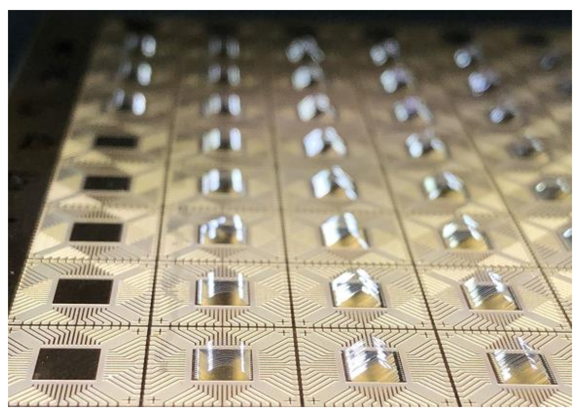
推拉力测试（刘凯报告）

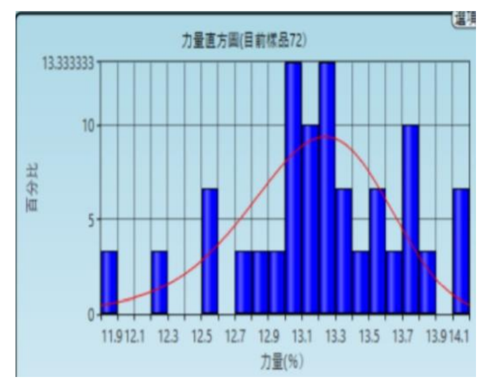
- 推拉力测试机测定引线的强度及损坏方式，相应调整打线机的参数（考虑焊板材质等因素）或是更换劈刀后重新确认参数





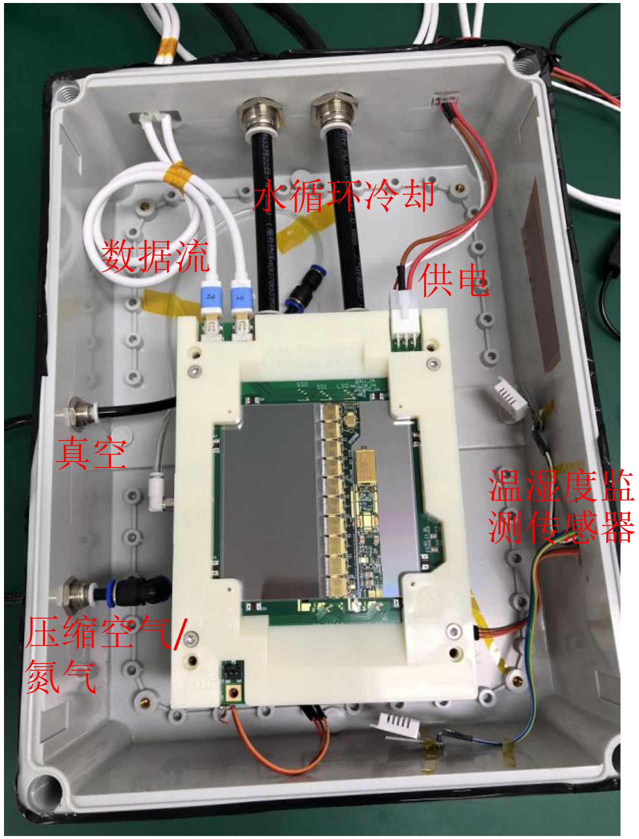
专用练习板

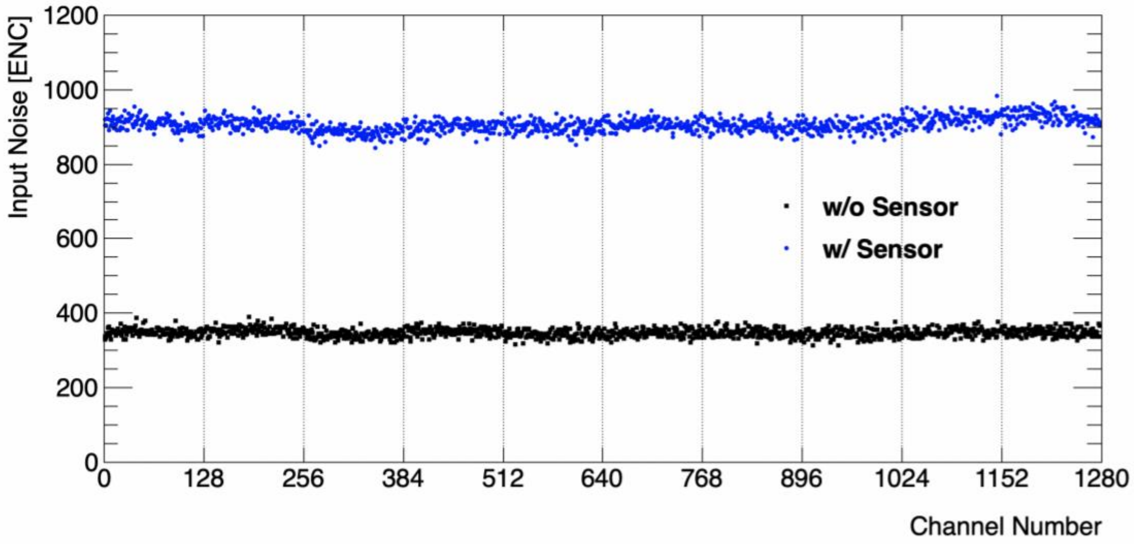




电子学测试（张登峰报告）

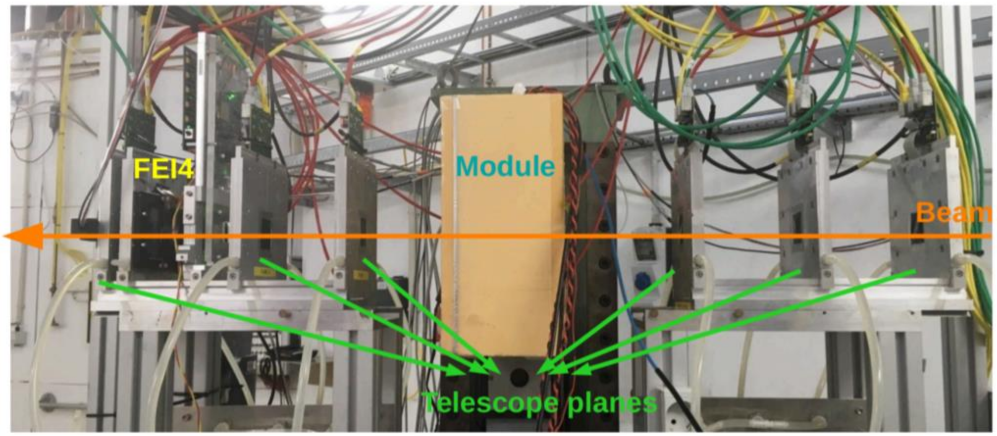
- 确定芯片（+传感器）工作正常，测定增益、噪声水平等等
  - 数据获取系统：芯片供电、参数配置
  - Pedestal Scan -> Strobe Delay Scan -> 3-Point Gain -> Trim Range -> Response Curve -> Noise occupancy

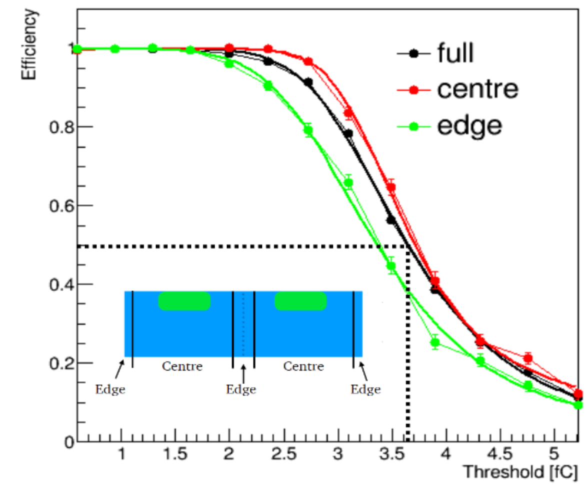




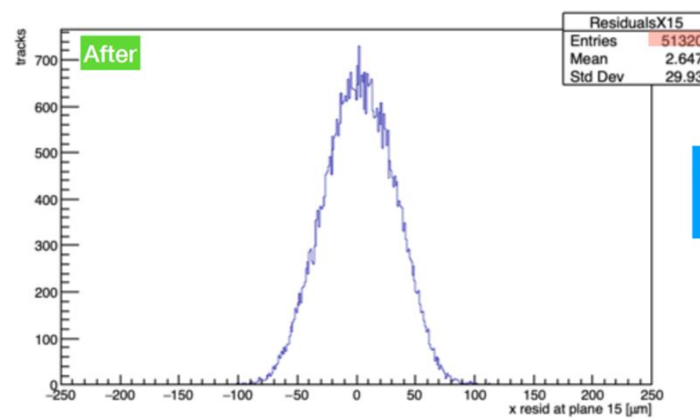
束流测试

- **标定硅探测器性能关键步骤。****高能所承担桶部模块束流测试及分析工作**，包括测试平台的搭建、实验值班、数据分析和重建软件开发等。





- 部分实验数据存在**不同步问题**，通过离线方式成功恢复（20%提升至超过80%）

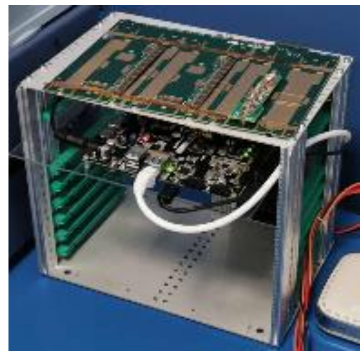


- 将参与11月份在DESY的束流测试
  验证辐照后的STAR模块可正常工作
  → Module PDR(2021.06)

即将开展的工作

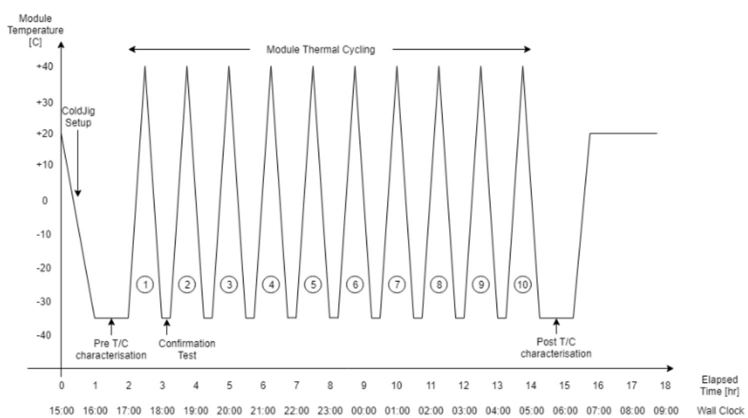
- **复合板(Hybrid) 老炼测试** (同时36个)
  - **100 小时@ 40**℃

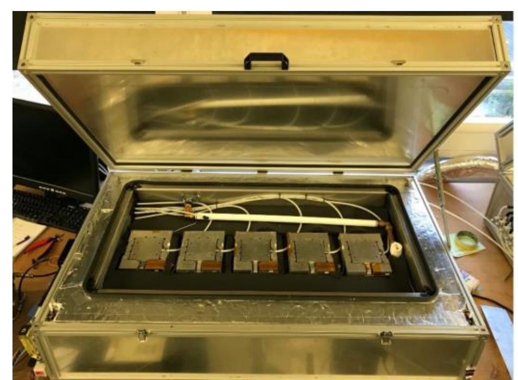
等待测试版、机箱及背板



环境箱已就位

- **模块热力学循环测试**（ **-35**℃**至 +40**℃**，循环10次，共计 12 小时**）





Cold Box 在Warwick组装
通过测试后将运至国内

生产点审核准备

Date		Powerboards UK	Powerboards China	UK Hybrids			UK Modules										
				B'ham	L'Pool	RAL/IHEP	Bham+Warv	Liv+Shef	Glasgow	Cambridge	RAL	TOTAL/month	China Hybrids	China Modules			
Nov-19																Global	100%
Dec-19	v2a	30														US	50%
Jan-20		6														China	5%
Feb-20	76	6														UK	45%
Mar-20		6															
Apr-20		6	10														
May-20		6															
Jun-20		6															
Jul-20		6		12	12							module total					
Aug-20		16		18	18				2	2	2	6					
Sep-20		23		24	24		2	2	4	4	4	16		LS	SS		
Oct-20		10		24	24	6	4	4	5	5	5	23	6				
Nov-20	v3	35	2	24	24	6	5	5	0	0	0	10	6				
Dec-20		40	4	20	20	6	7	7	7	7	7	35	6	1	1		
Jan-21	267	40	7	20	20	6	8	8	8	8	8	40	6	2	2		
Feb-21		40	7	20	20	6	8	8	8	8	8	40	6	4	3		
Mar-21		40	8	19	19	6	8	8	8	8	8	40	6	4	3		
Apr-21		40	4	7	7	6	8	8	8	8	8	40	6	4	4		
May-21				3	3	6	8	8	8	8	8	40	6	1	3		
Jun-21				**191**	**191**	**48**	**58**	**58**	**58**	**58**	**58**	***290***	48	16	16		
Jul-21																	
Aug-21										modules	**290**						
Sep-21																	
Oct-21																	
Total																	

Assumptions: probed and diced ABCStar available Jun 2020; start PP with prototype HCCStar; pre-production HCCStar available Sept 2020

Assumption: probed and diced AMACv3 available in Sept 2020 + time to prepared PB = v3 available Nov20

Yellow = hybrids with prototype HCCStar (84); site qualification

Green = RAL/IHEP site qualification

Orange = modules with prototype HCCStar and PB v2a (55); site qualification

Green = China hybird site qualification

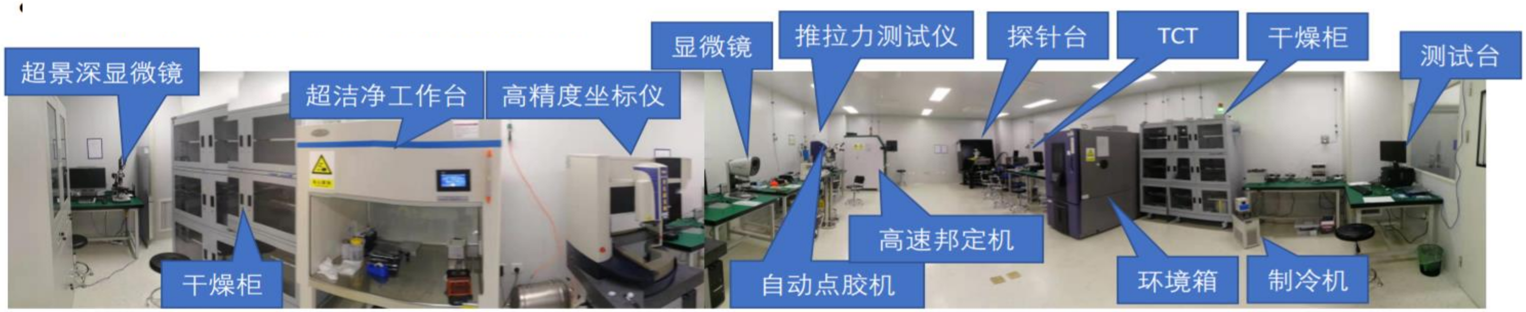
Dark green = China module site qualification

For prototyping phase (now to Jun 2020)
5SS & 5LS per site = 50 PB
Hybrid panel tesing = 15 PB
Total = 65 PB for the UK
Already got 30 in hand

- 计划10月开始复合板/模块生产点审核，通过后进入预生产（小批量）。
- 审核改为视频方式，具体方案待定。器件生产受疫情影响，可能会影响预生产

高能所洁净间状态及人员队伍

- 项目专用洁净间正常运行：80平米、万级。
- 关键设备陆续到位。按模块制作流程逐步优化空间布局，实现高效批量生产。



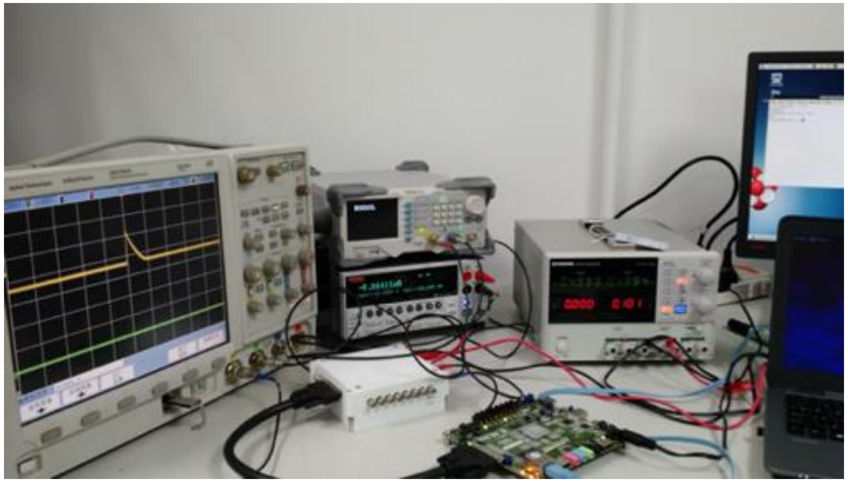
Name	Task	Description	2019 FTE	2020 FTE	2020 From	2020 To
Barreiro Guimaraes da Costa, Joao	532954	ITk Strips General Tasks	0.10	0.1	Jan	Jun
Buchanan, Emma	532954	ITk Strips General Tasks	0.67	1	Jan	Jun
Chen, Xin	532954	ITk Strips General Tasks	0.10	0.1	Jan	Jun
Chen, Yebo	532954	ITk Strips General Tasks	0.33	0.5	Jan	Jun
Li, Yiming	532954	ITk Strips General Tasks	0.25	0.25	Jan	Jun
Liang, Zhijun	532954	ITk Strips General Tasks	0.10	0.1	Jan	Jun
Liu, Kai	532954	ITk Strips General Tasks	0.50	0.5	Jan	Jun
Liu, Peilian	532954	ITk Strips General Tasks	0.17	0.5	Jan	Jun
Lou, Xinchou	532954	ITk Strips General Tasks	0.10	0.1	Jan	Jun
Lu, Weiguo	532954	ITk Strips General Tasks	0.50	0.5	Jan	Jun
Shi, Xin	532954	ITk Strips General Tasks	0.50	0.5	Jan	Jun
Yang, Yuzhen	532954	ITk Strips General Tasks	1.00	1.0	Jan	Jun
Zhang, Dengfeng	532954	ITk Strips General Tasks	0.50	0.5	Jan	Jun
Zhu, Hongbo	532954	ITk Strips General Tasks	0.50	0.5	Jan	Jun

课题三：CMOS 硅微条探测器

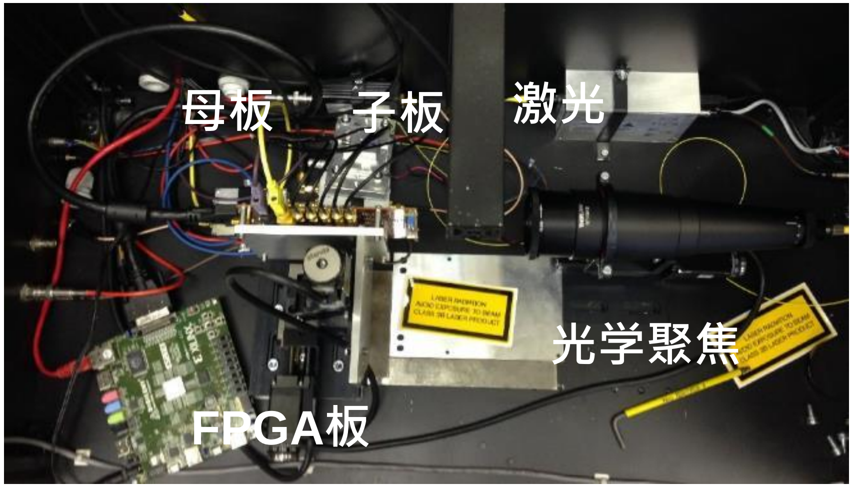
CMOS硅微条探测器性能研究

- 基于CMOS工艺设计制作的硅微条探测器，具备低造价、低物质量等优点，可以替代传统型硅微条探测器 → 前沿探测器技术预研，未来对撞机实验径迹探测器重要候选技术。

- 评估CMOS硅微条探测器性能，完成方案可行性研究。



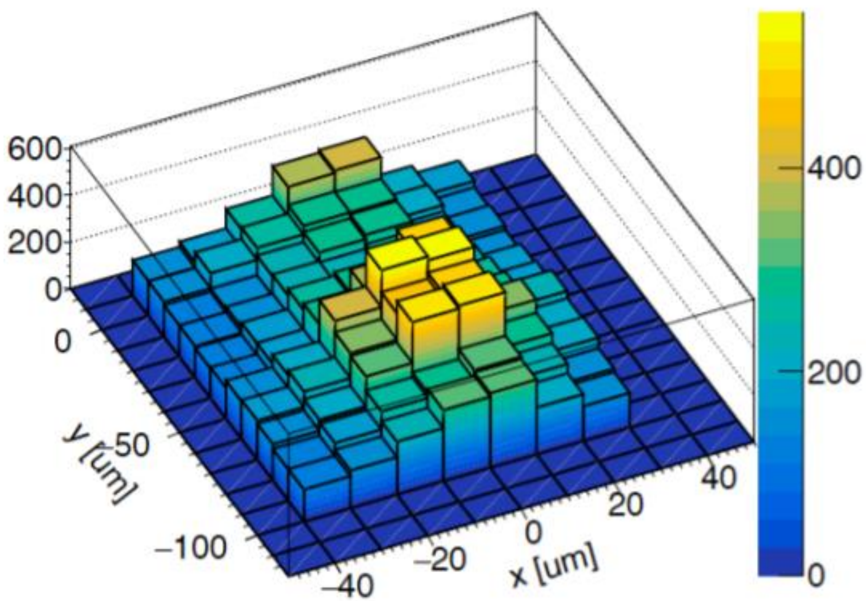
电子学测试系统

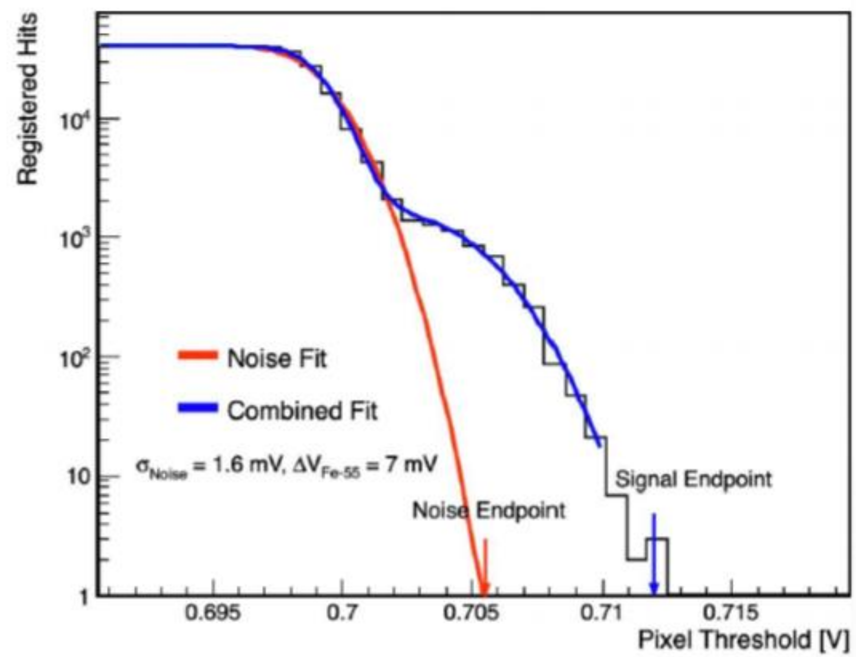


电流瞬态扫描（TCT）系统，测试传感器结构。

测试进展（CHESS2 – CMOS HV Evaluation for Strip Sensors）

- ✦ 对CHESS2开展更多测试，包括激光、Fe-55、Sr-90放射源响应等。
- ✦ 内部Trimming电路不工作，只能采用单像素配置的方式进行测试。





- Hiroshima会议文章已接收： Study of the HV-CMOS active strip sensor (CHESS2) for future silicon trackers

国际合作

- 与英国卢瑟福实验室（RAL）合作，开展硅微条探测器模块的设计和建造
- 英国卢瑟福实验室不仅是现有硅微条探测器（SCT）的主要建造者，也是升级项目中最早开展预研工作的单位，具备雄厚的硅微条探测器研制能力。

2016年9月19日，团队正式访问卢瑟福实验室，与RAL以及英国合作组协商合作相关事宜。

- 选派职工、博士后轮流常驻RAL，共同完成了原型样机、工程样机等，掌握关键技术，确定了双方在批量生产阶段的分工。
- **建立长期合作关系，共同开展更多研究。**

芯片禁运问题

- CERN已经申请到美国商务部出口许可，高能所与CERN签订正式科研合作协议。

- 等待中国商务部批准终端用户声明的申请。

COLLABORATION AGREEMENT
REFERENCE KN4809/EP
(THE "AGREEMENT")

BETWEEN: THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH ("CERN"), an Intergovernmental Organization having its seat at Geneva, Switzerland, duly represented by Eckhard Elsen, Director for Research and Computing,

AND: THE INSTITUTE OF HIGH ENERGY PHYSICS OF THE CHINESE ACADEMY OF SCIENCE ("IHEP"), established at 19B Yuquan Road, Shijingshan District, Beijing, 100049, China, duly represented by Yifang Wang, Director,

Re-Export License
D1177529
Validated: November 18, 2019
Expires: November 30, 2025

UNITED STATES DEPARTMENT OF COMMERCE
BUREAU OF INDUSTRY AND SECURITY
WASHINGTON, D.C. 20230

Type of ASIC	Quantity	Estimated Value Per Unit (in U.S. Dollars)	Total Value Per Type of ASIC (in U.S. Dollars)
ABC*	7500	9	67,500
HCC	750	5	3,750
AMAC	600	5	3,000
GBTIA	1200	5	6,000
GBLD	50	5	250
GBTSCA	10000	10	100,000
GBTX	50	20	1,000
linPOL12V	600	5	3,000
BPOL12V	5100	10	51,000
		Grand Total Value (in U.S. Dollars) of ASICs	235,500

文章发表


Testbeam studies of barrel and end-cap modules for the ATLAS ITk strip detector before and after irradiation
Version 0.3
ATLAS17LS – a large-format prototype silicon strip sensor for long-strip barrel section of ATLAS ITk strip detector
Study of CMOS strip sensor for future silicon tracker
The ABC130 barrel module prototyping programme for the ATLAS strip tracker

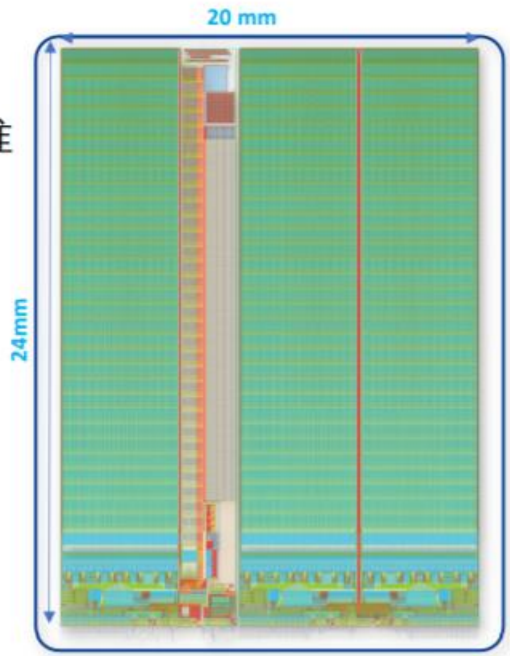
小结与展望

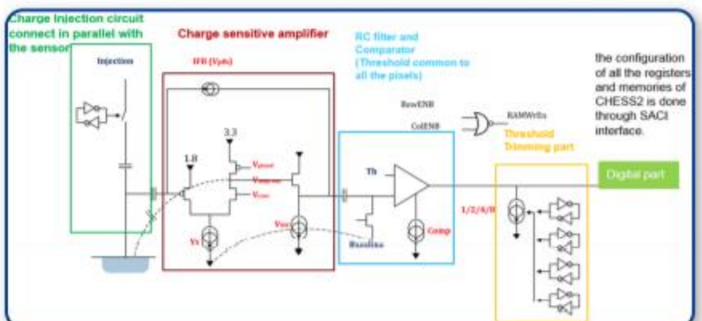
- ATLAS 硅微条径迹探测器升级项目进展顺利，完成本年度课题目标
  - 课题一： 前端读出电子学设计 – 已完成设计、联调
  - 课题二： 硅微条探测器模块设计和建造 – 完成原型设计建造，准备开始预生产
  - 课题三： CMOS 探测器性能研究 - 性能测试已完成
- 全力准备生产点评估，启动预生产。

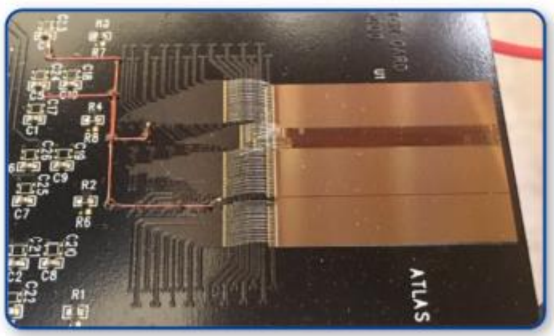
Backup

课题三：CMOS硅微条探测器性能测试

- 基于先期研制的CMOS硅微条传感器，开展主要性能测试（电荷收集效率、噪声水平、空间分辨率等）
- 测试结果用于改进传感器设计，并为集成的读出电子学设计提供参考基准
- 基于FPGA开发CMOS硅微条传感器的数字读出芯片，构建原理样机
- 通过实验室放射源和试验线束完成性能标定

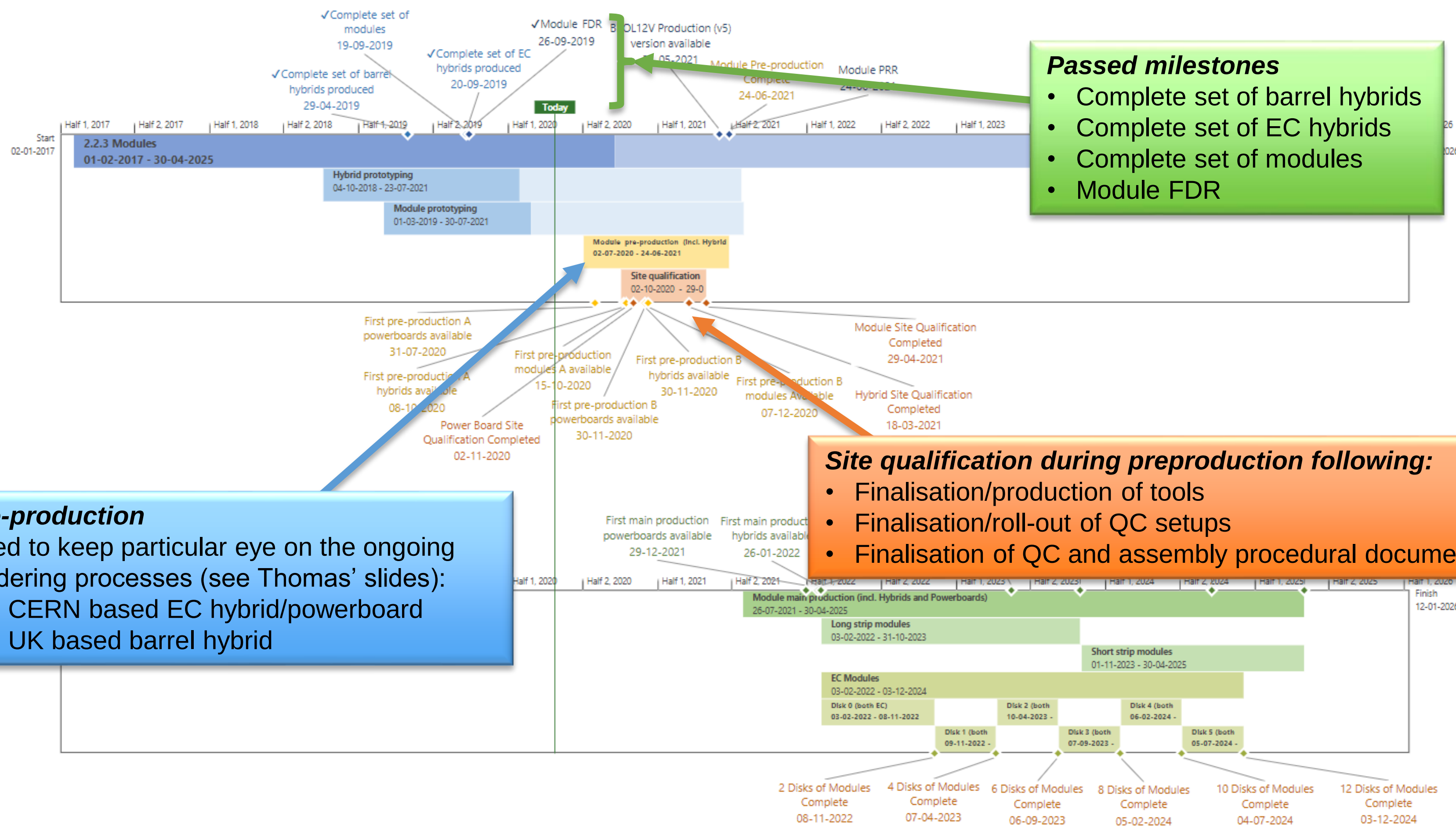






与SLAC/UCSC 合作

WBS 2.2.3: Modules – Schedule Overview



Passed milestones

- Complete set of barrel hybrids
- Complete set of EC hybrids
- Complete set of modules
- Module FDR

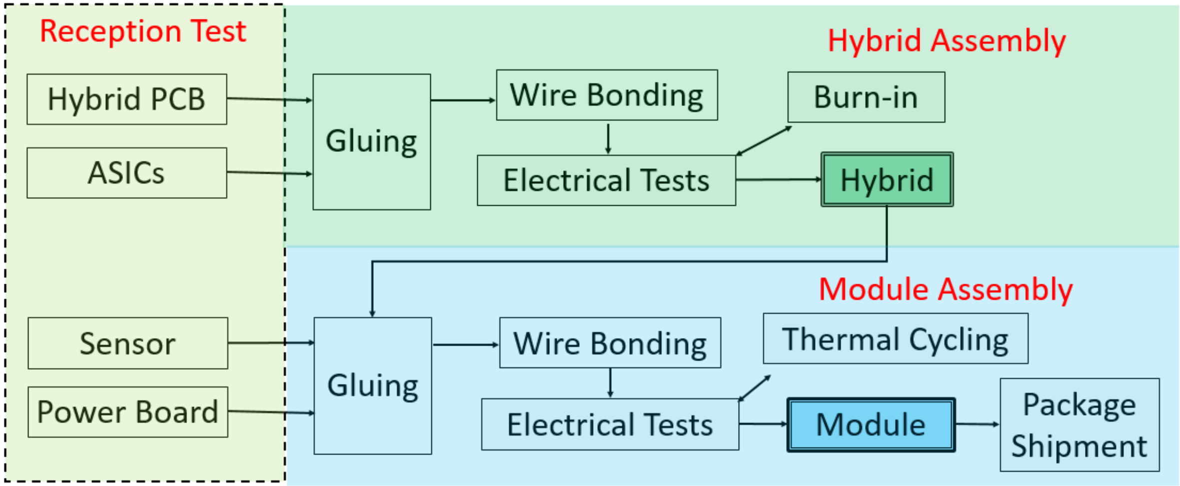
Site qualification during preproduction following:

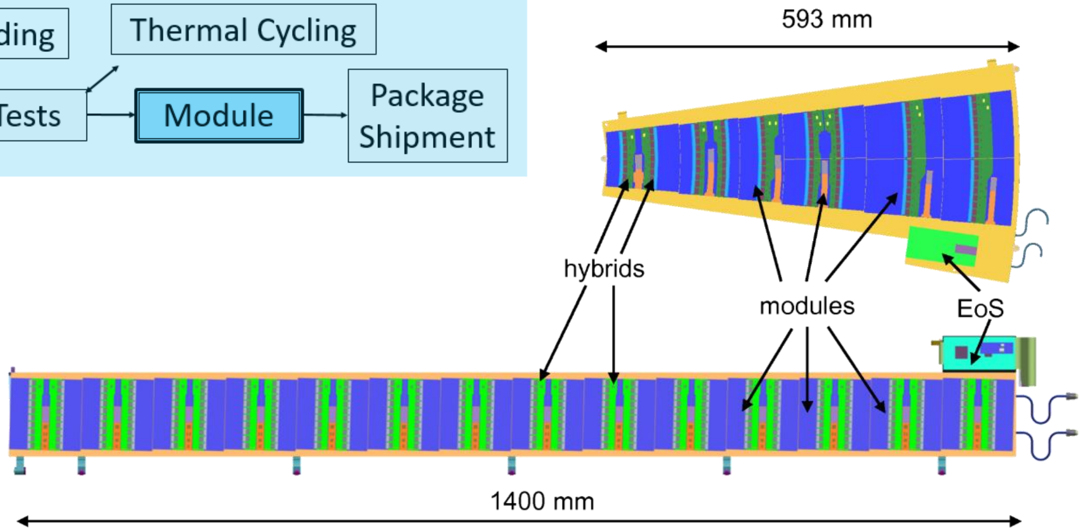
- Finalisation/production of tools
- Finalisation/roll-out of QC setups
- Finalisation of QC and assembly procedural documents

Pre-production

Need to keep particular eye on the ongoing tendering processes (see Thomas' slides):

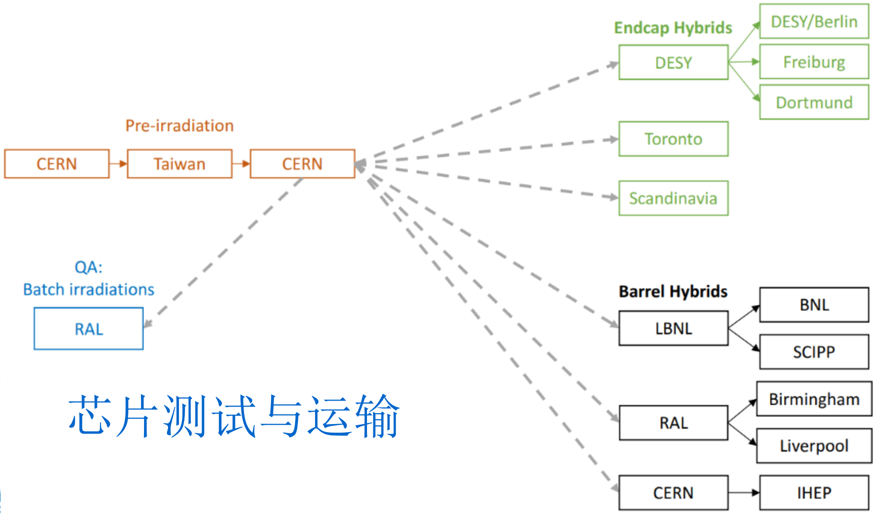
- CERN based EC hybrid/powerboard
- UK based barrel hybrid


Reception Test
Hybrid PCB
ASICs
Sensor
Power Board
Hybrid Assembly
Gluing
Wire Bonding
Electrical Tests
Burn-in
Hybrid
Module Assembly
Gluing
Wire Bonding
Electrical Tests
Thermal Cycling
Module
Package Shipment


593 mm
hybrids
modules
EoS
1400 mm

Irradiations at INER

- Initial pre-irradiation studies were done with xrays at RAL
- All results shown here come from Co-60 irradiation at INER in Taiwan
  - Good relations with INER via ATLAS-Taiwan colleagues
  - Good experience using the site in the past
  - Attractively low price for full production pre-irradiation O(10k) plus shipping
  - Only negative is time for shipping and the export license
- Facility has a wall of Co-60 with a conveyor belt going around it
  - Irradiated to approx. 8 Mrad
- Drawer which we use allows boxes with dimensions of 40x30x7cm
- ABC130 pre-irradiation done as single 4" gel-pak
- ABCStar pre-irradiation done in waffle/gel-paks taped into standard 28x19x6 cm box
  - In Taiwan just had to take box, put on conveyor belt and take off when done
  - Takes about 24 hrs for actual irradiation



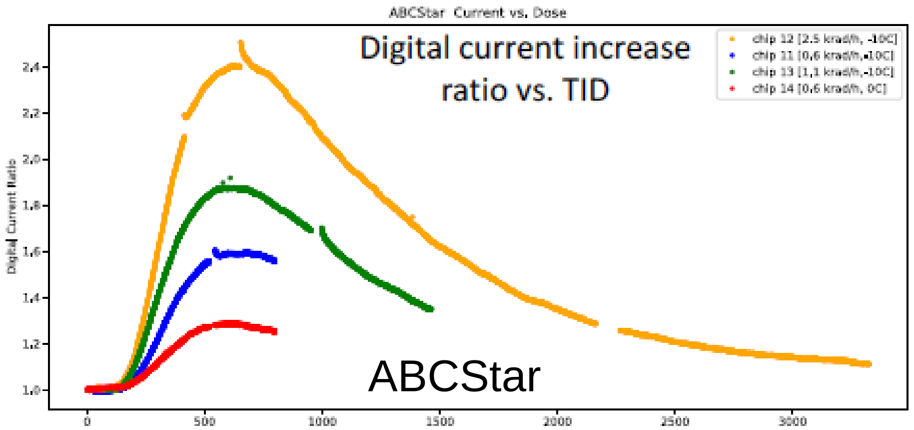
4

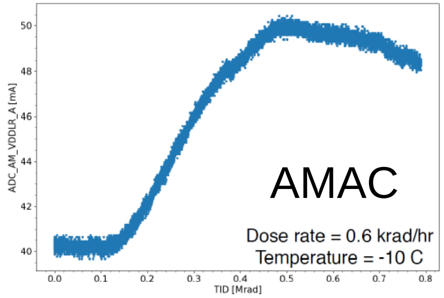
芯片测试与运输

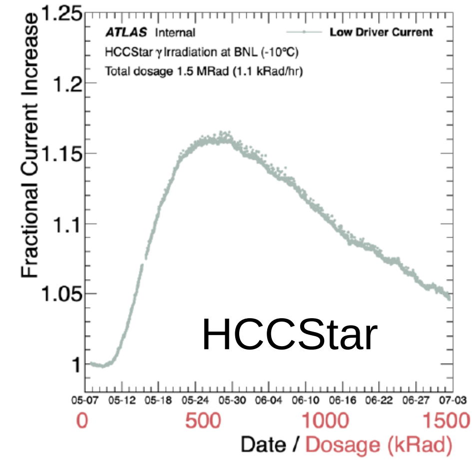
Test results: irradiation at low dose rate

- One-off tests on prototype and pre-production ASICS
  - BNL gamma ray source
- Low temperature, low dose rate irradiation to reproduce experimental conditions
- Results for ABCstar consistent with ABC130
  - Feed into thermal-power model of Strips

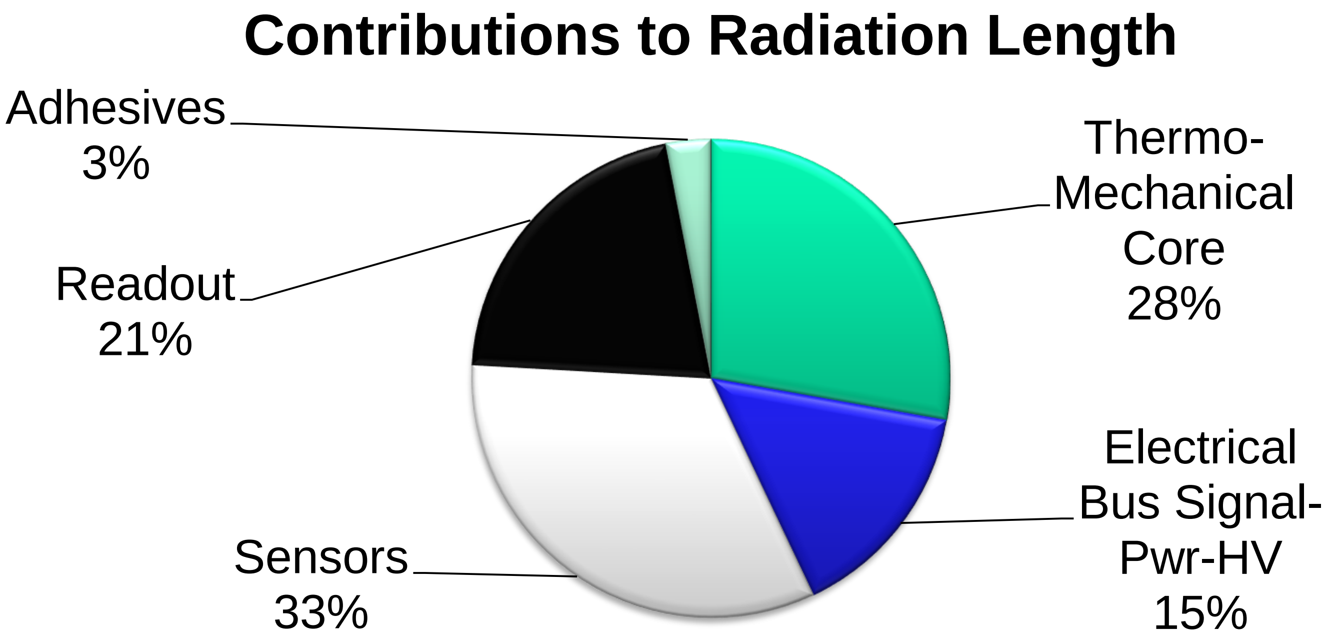
T (°C)	Dose rate (krad/h)	ASIC
-10	0.6	ABCStar
	1.1	ABCStar, HCCStar, AMAC
	2.5	ABCStar
0	0.6	ABCStar



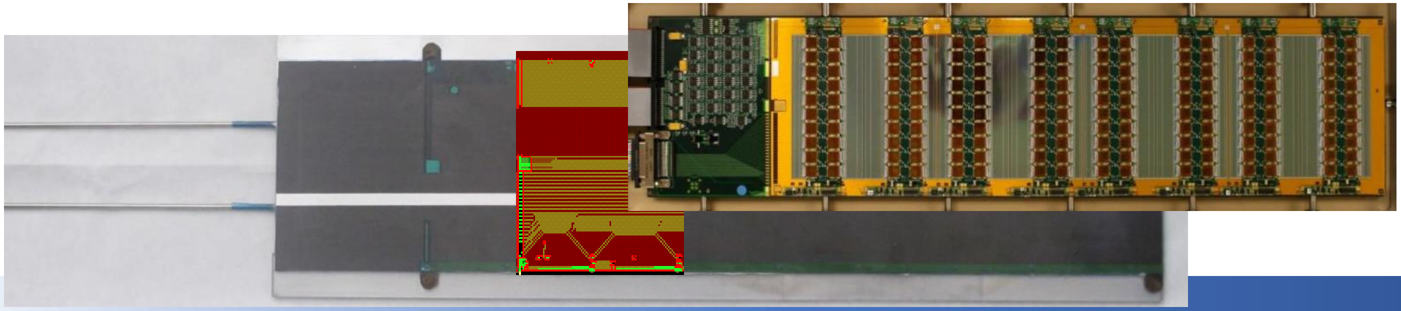




A Low Mass Structure



- Total material/stave is in the range 2.0-2.5% Xo

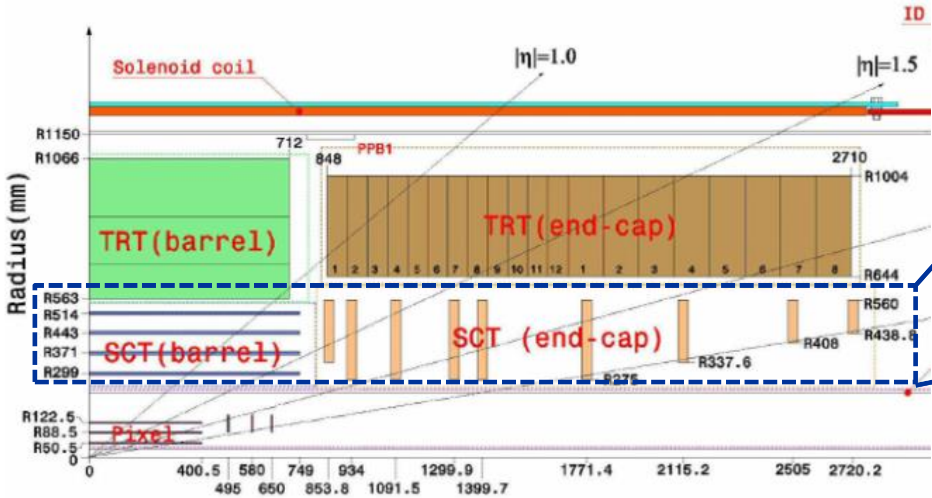


Scale

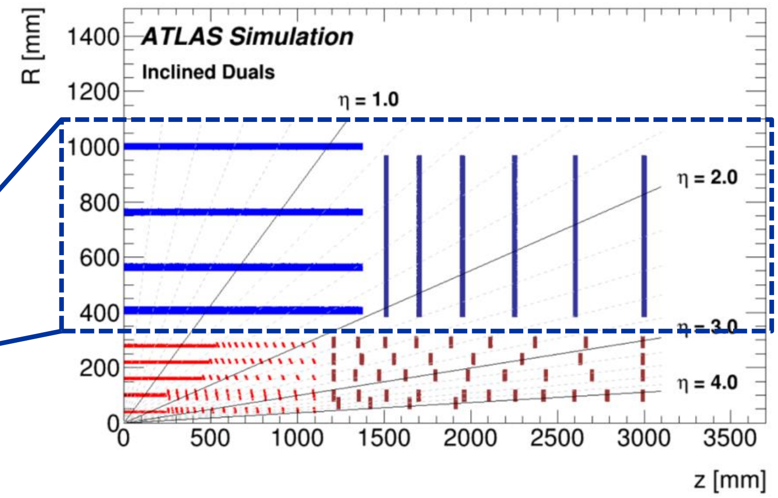
- 163 m^2 of silicon
- 233,856 FE ASICs
- 17,888 modules
- 392 staves
- 384 petals
- ~$60M in “CORE” units
- ~$225M in USA units (labor and inflation included)

ATLAS ITk Layout（from TDR）

Current



Future



– **High-granularity**

– **Radiation-hard**

– **Extended coverage to η of 4**
  ($|\eta| < 2.5$ for Run 2)

$$\eta = -\ln\tan(\frac{\theta}{2})$$

- **200m² of silicon** with 5G pixels and 80M strips

The Strip detector : 4 barrel layers and 6 end-cap disks on each side

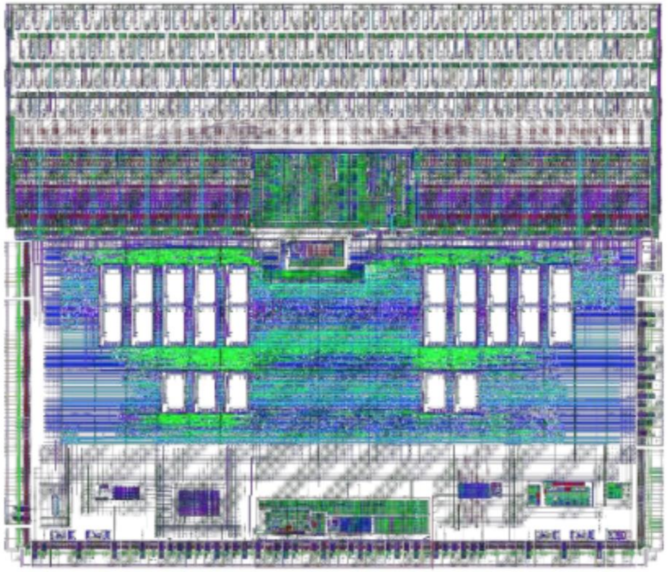
- **Double modules with a small stereo angle** to provide 2D measurements

ABCStar: improving SEE protection

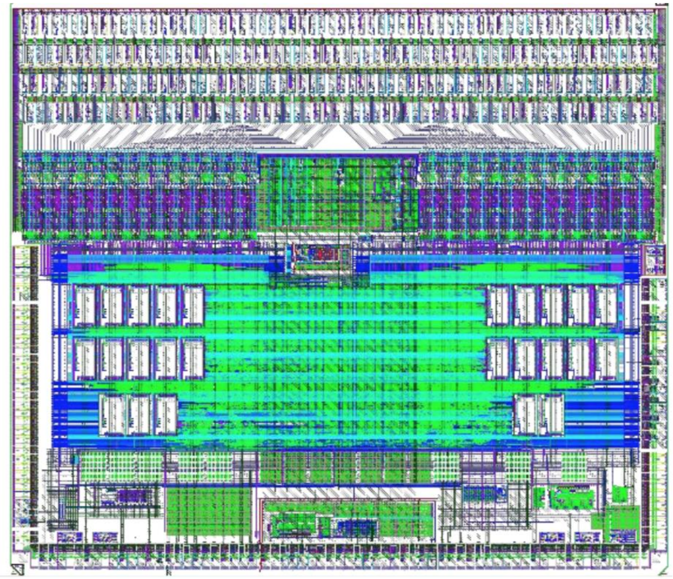
We decided to add full triplication to the ABCStar design, including clocks and resets, using CERN’s TMRG tool: systematic, widely used at CERN.

On the ABCStar, we could fit the additional logic and routing (metal interconnection), seen in green below.

Prototype ABCStar

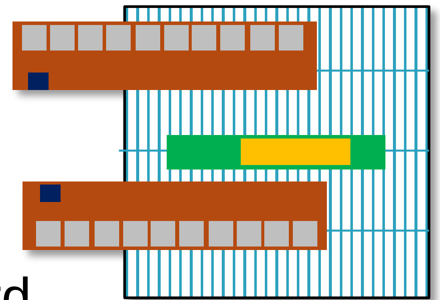


Pre-production ABCStar



Barrel Modules and Staves

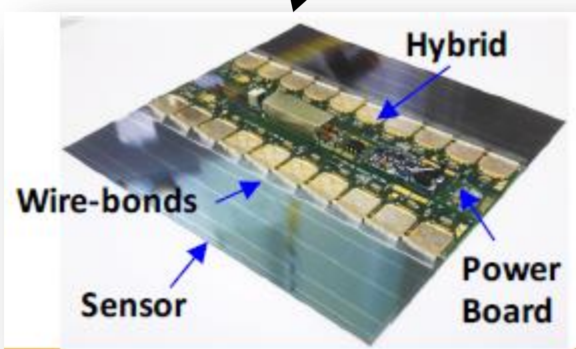
1 Sensor
+20 FE chips
+2 controllers
+2 hybrids
+1 Power board
=1 SS Module

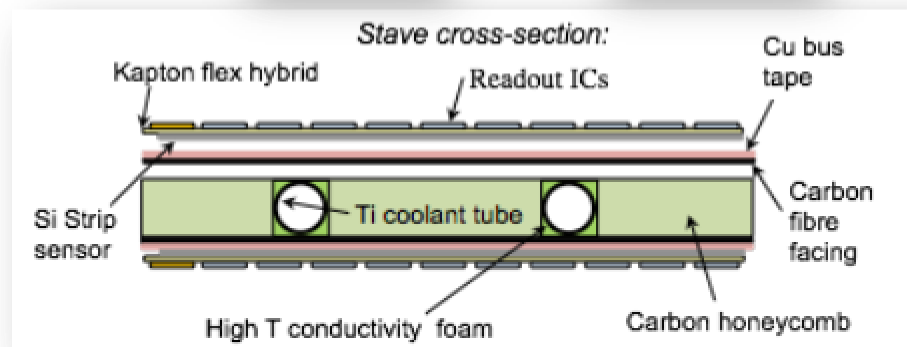


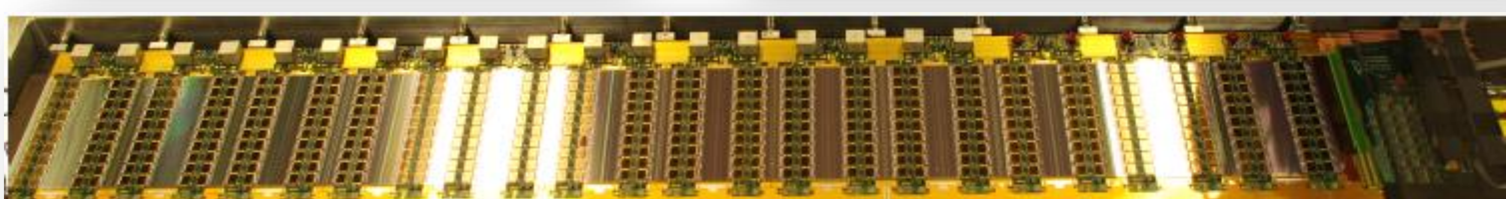
x 28 +

+

=







运输盒

- To make **300 transport boxes**: spacer + top/bottom covers
- To modify the mold used last time (reduced cost), expected delivery dates: 40 days.
- Contract in preparation

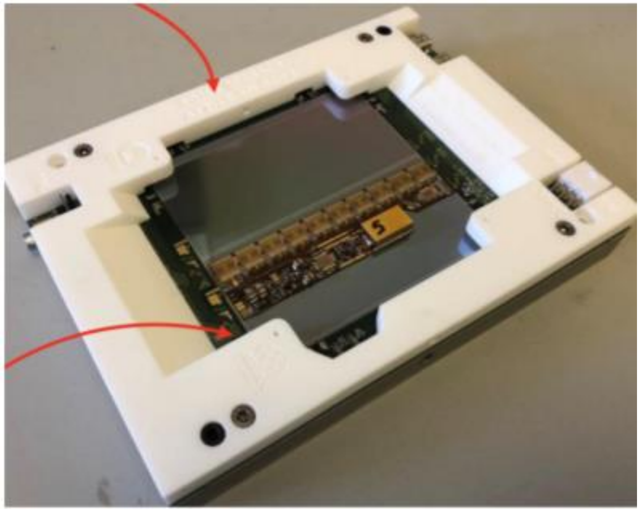
报 价 单（quotation）

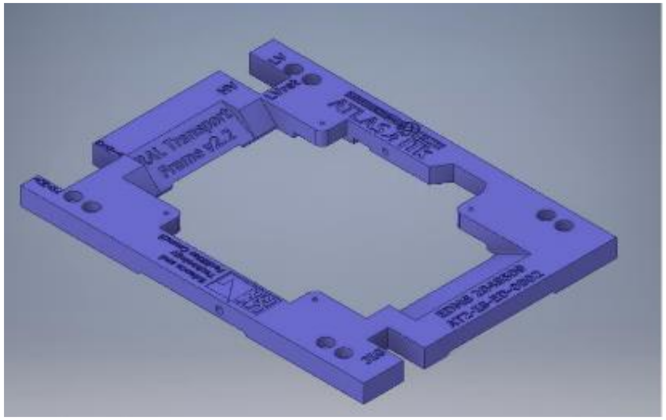
客户：中国科学院高能物理研究所
朱宏博：18511681021

NO	名称	材料	单价（元）	数量	小计（元）	加工周期	图片	备注
01	Transportframe2.2 模具	P20 模具钢	13500	1 套	13500	30 个工作日		原模具基础更改
02	Transportframe2.2 板	防静电 ABS	20	300 件	6000	40 个工作日		注塑加工
03	boxDetails 上盖板	PMMA 防静电板	58	600 件	34800	30 个工作日		板加工
				总计：	54300 元	伍万肆仟叁佰元		

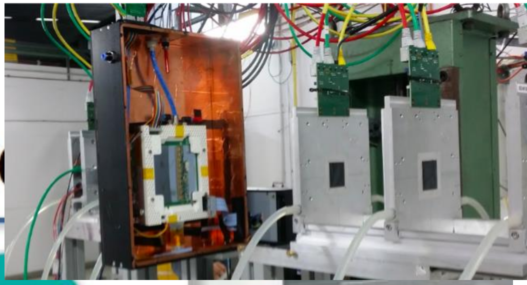
另：1，产品价格含表面处理、含包装、含增值税 13%、含运输至高能所费用。
2，未尽事宜见双方技术协议。

北京瑞隆祥模具有限公司 Beijing Relontion Mould Co.,Ltd
王晓华
TEL：010--89774572 FAX：010--89774572
MOBILE: 13683053196
2020-07-14

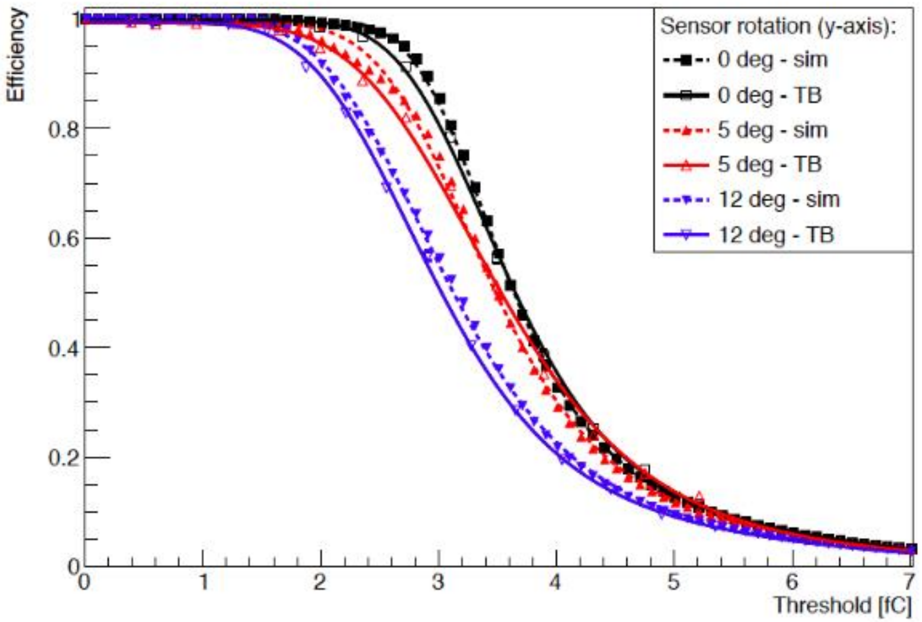


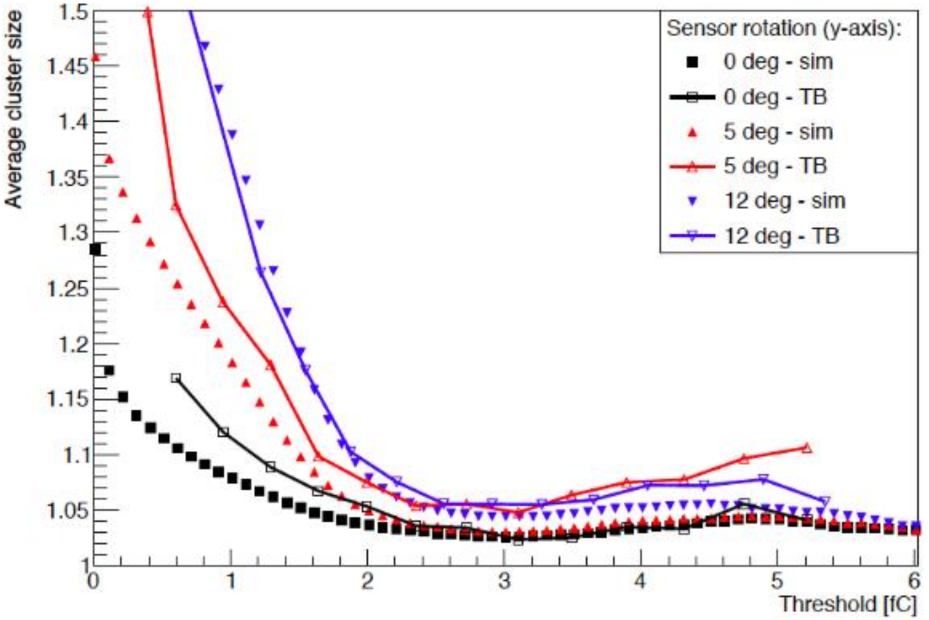


LS module - Test beam vs. simulati



- Simulation of simplified LS module using Allpix² framework
  - Compare efficiencies and mean cluster size



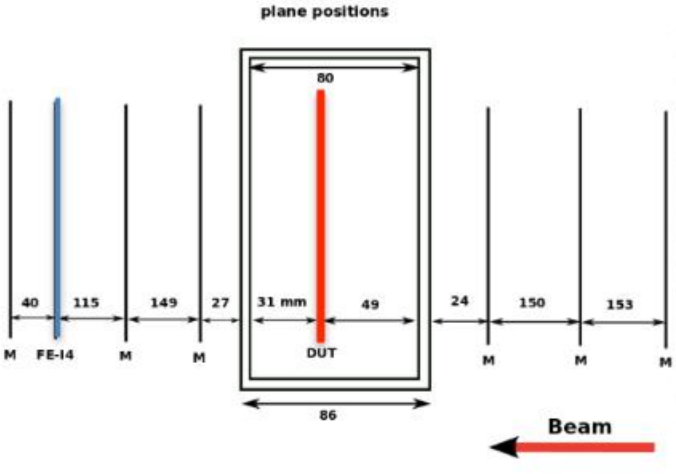


- Work in progress
  - Electric field maps and simulation being refined

- Overall good agreement of efficiencies from test beam and simulation
  - For average cluster size, trend is correctly described

Modules and Beam Tests

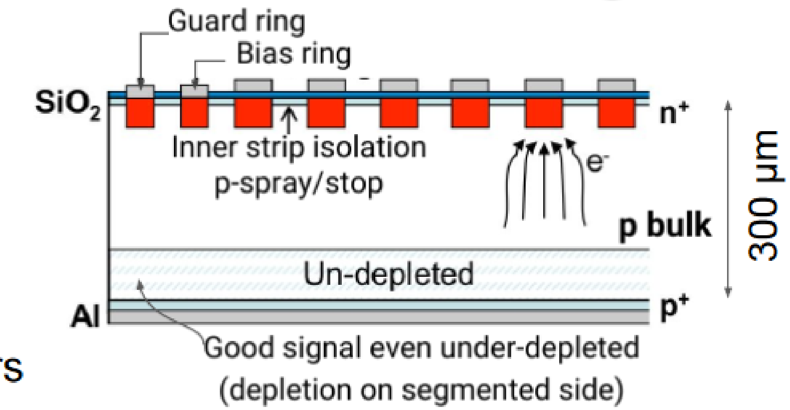
- In all cases EUDET-type beam telescopes comprised of six Mimosa planes and one FE-I4 or Alpide timing plane
    - DURANTA at DESY
    - ACONITE at CERN
- Tracking resolution of
    - 5-10 μm at DESY
    - 3 - 5 μm at CERN
- Telescope and device under test (DUT) controlled and read-out using EUDAQ2

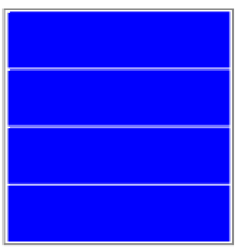


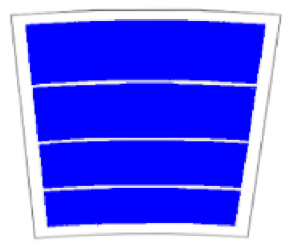
ITk Strip Detector

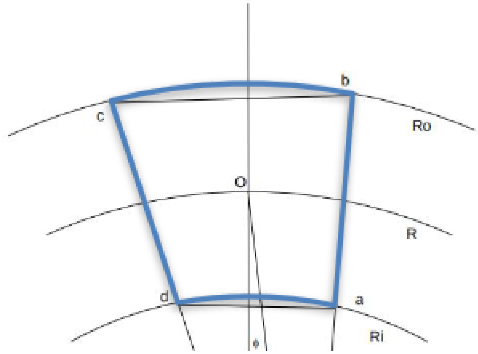
- n+-in-p float zone silicon sensors
  - 300 μm thick
  - No radiation induced type inversion
- Strip pitch around 75 μm

- **Two classes of sensor geometry**
  - Rectangular 10cm x 10cm barrel type sensors
  - "Trapezoidal" end-cap type sensors
    - Strips point at point close to beam axis



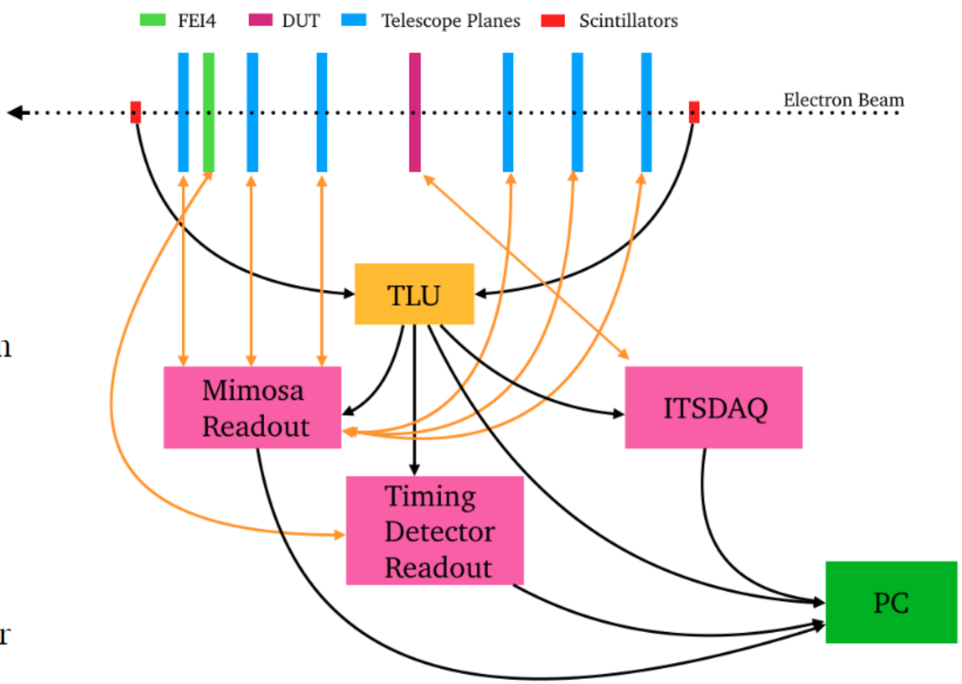






The Desynchronisation Problem

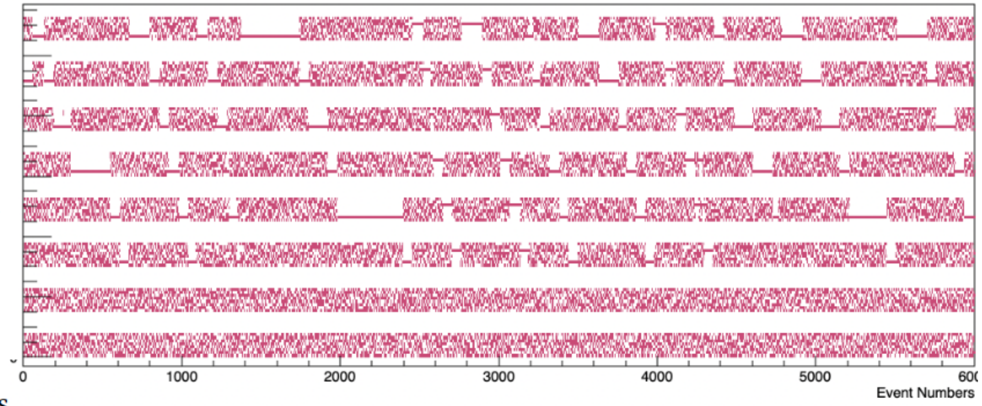
- During analysis of **April 2019 Testbeam** data we found that only **~30%** of events within a run were synchronised
- What does desynchronised data mean?
  - There is a mix up of the sub-event information
  - Events are assembled with sub-event information from each subsystems
  - Sometimes the wrong DUT event information is assigned to the wrong ITSDAQ event information
  - The reason for this is not fully understood but could be because of missing sub event information or similar
- Need to compare the event IDs
  - **TTCBCID from ITSDAQ & RAWBCID from the DUT**



Do we understand the desync?

Observations

- After presenting at ITk week there was a discussion between Bruce, Jens, Matt and Paul. They found it interesting that:
  - The RAWBCID from the ABC* was always ahead of the TTCBCID from ITSDAQ (x+i to get the correct BCID to be in sync)
  - That the step count resets once reaching x+5.



Explanation and Fixes

- Sometimes a Beam Count Reset (BCR) is sent to reset the BCIDs
- The TTCBCID and RAWBCID in the data are basically the BCID according to the FPGA (ITSDAQ) and according to the (ABC*) ASIC, respectively,
  - It appears when there was a BCR it was resetting the ASIC BCID (RAWBCID) but not resetting the FPGA BCID (TTCBCID), hence the step function with the TTCBCID[i]-RAWBCID[x+i]
- There is a timeout counter, if it doesn't find any data when it looks for it (in the queue), it marks a "timeout". When the timeout counter gets to 6 it starts a new burst
- This understanding has lead to a change that means the desync should not be an issue in the future
  - The firmware now has a feature that scans for BCRs in a software generated control stream sent to the chip/hybrid and resets the internal (TTC)BCID counter when it sees one