

ATLAS 实验硅微条径迹探测器升级

刘佩莲

参加单位：中科院高能物理研究所、清华大学

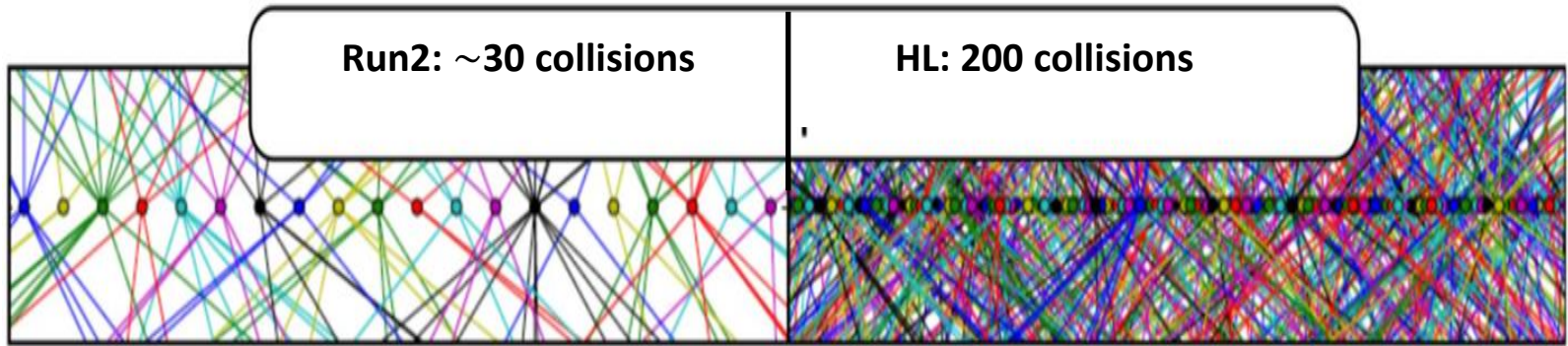
LHC探测器升级研讨会, 2020.8. 11-12

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

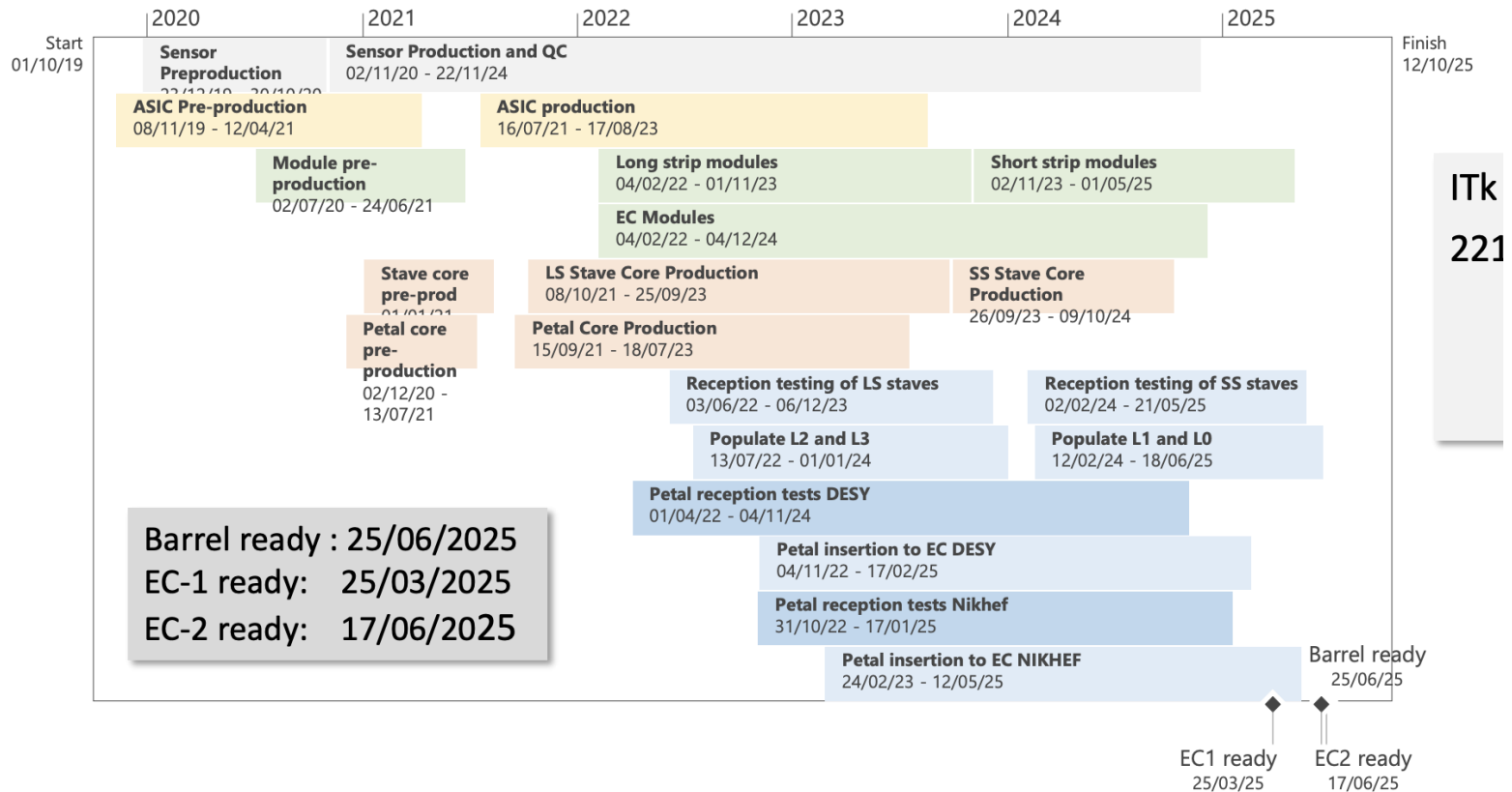
- 目标研制抗辐照、高分辨、快读出且低质量的硅微条探测器
- 完成1000个硅微条模块（10m²硅）并集成到ATLAS探测器
- ✦ **国内首次**在ATLAS实验承担大面积抗强辐照径迹探测器建造任务，并参与安装点的系统集成与联调工作。
- ✦ 系统掌握**建造抗辐照硅探测器**的关键工艺流程，获得**硅探测器系统设计、集成及调试**相关的关键技术，为以后自主设计此类复杂硅探测器系统奠定坚实基础。

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）



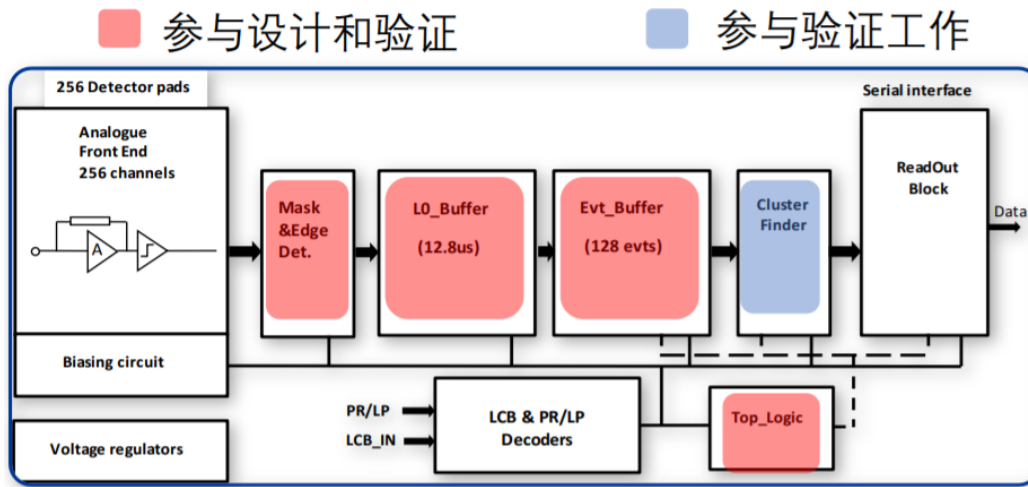
- ✦ **硅微条探测器模块预生产**（PRE-PRODUCTION）从2020年第三季度开始，持续1年时间，将完成模块批量生产总量的5%。
- ✦ **硅微条探测器(桶部+端盖)** 计划于2025年8月底完成系统测试，等待与硅像素探测器总装及后续安装调试

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

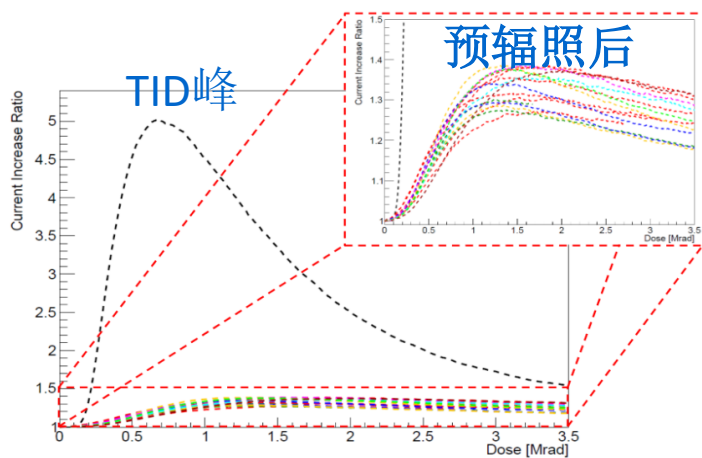


- ✦ 芯片用于探测器模块原型样机建造，已经过验证。联调通过，课题完成。
- ✦ 拓展性研究：强化抗辐照研究能力，为将来抗辐照加固设计提供参考。
 - ✦ 总辐照剂量（TID）
 - ✦ 单粒子效应

芯片预辐照

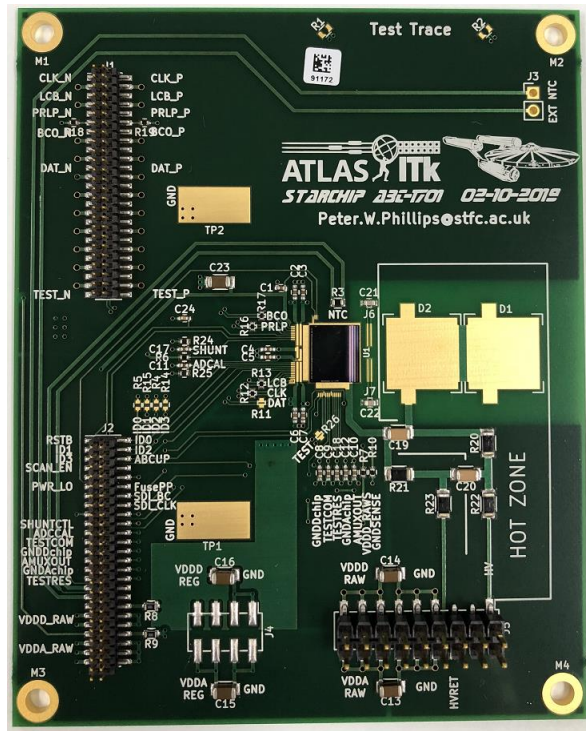
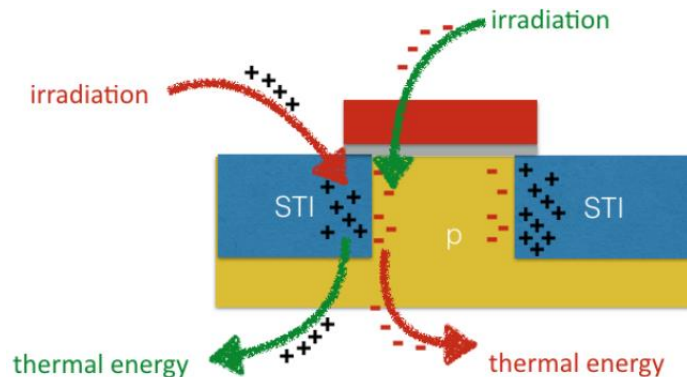
✦ 芯片经受辐射，由于TID效应，工作电流增大

- 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



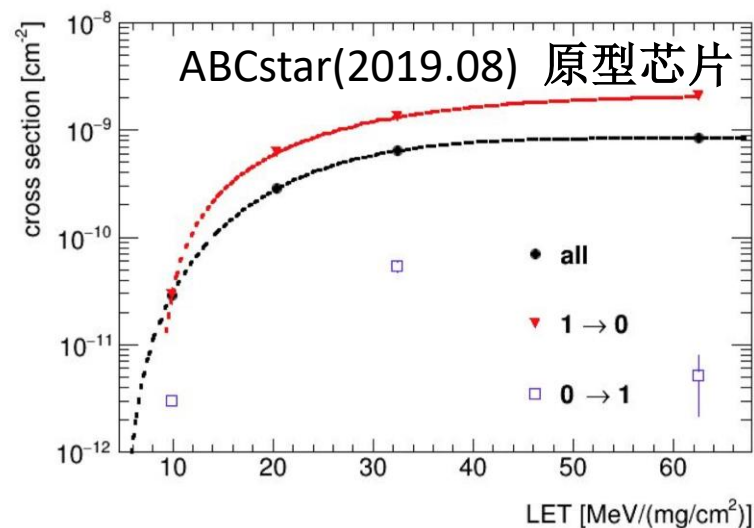
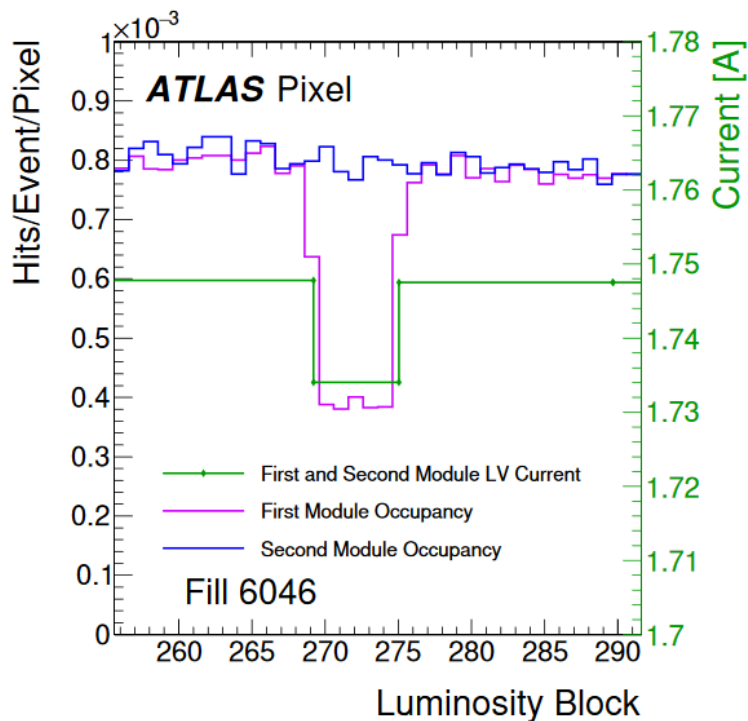
✦ 模块(预)生产将采用预辐照后的芯片，避开TID峰

✦ 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。

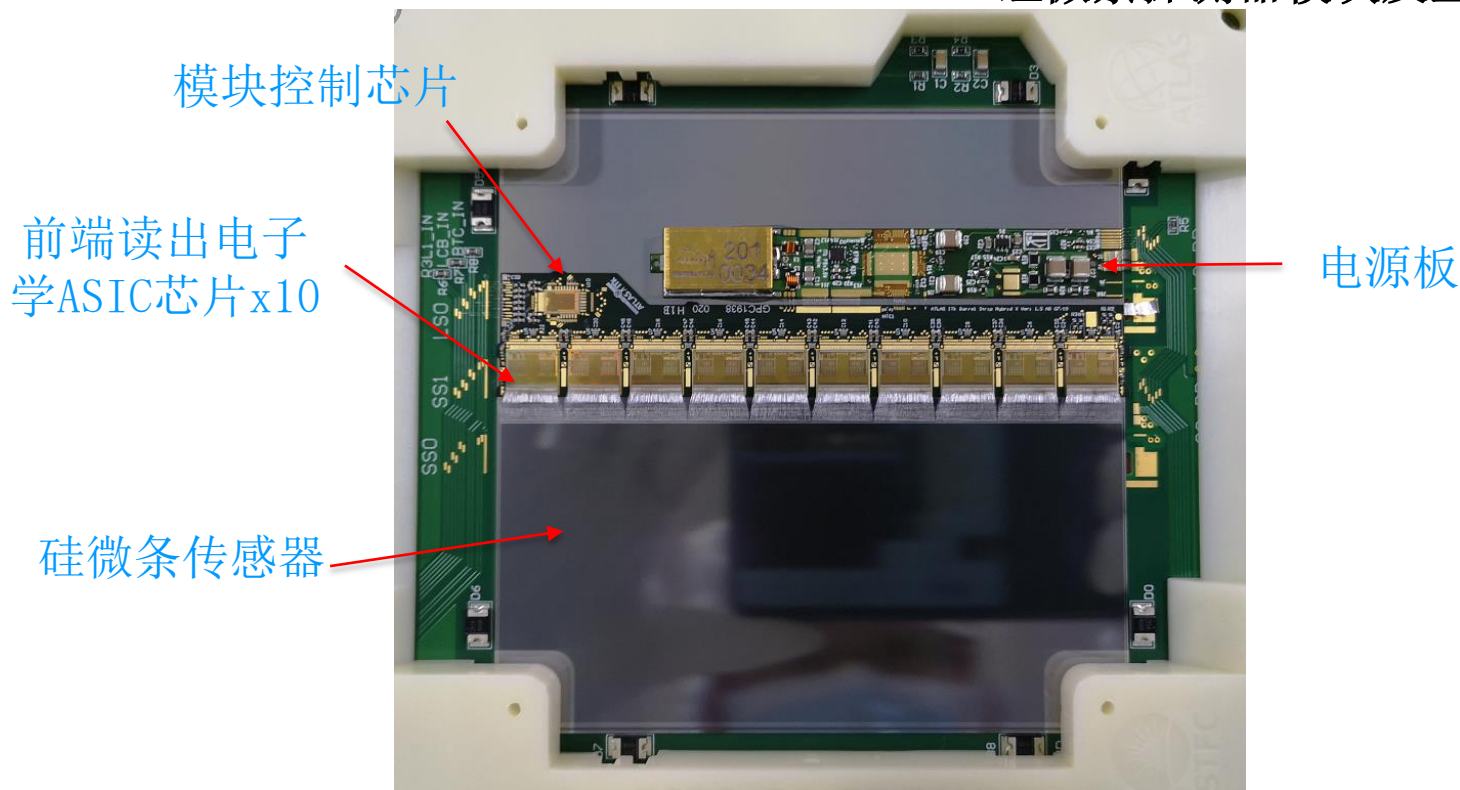
课题二：硅微条探测器模块性能研究 及建造

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

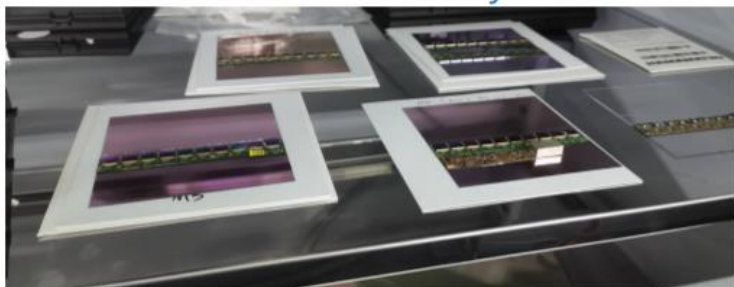


主要进展：硅微条探测器模块

- ✦ 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

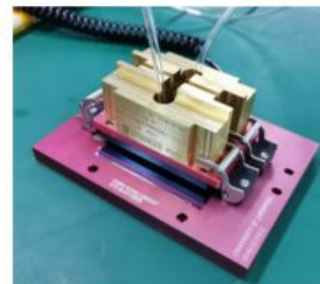
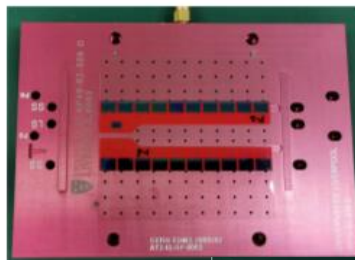


17LS sensor + 130 ASICs

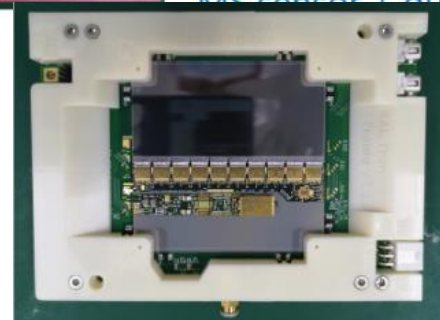


STAR 探测器模块

Glass sensor + dummy ASICs



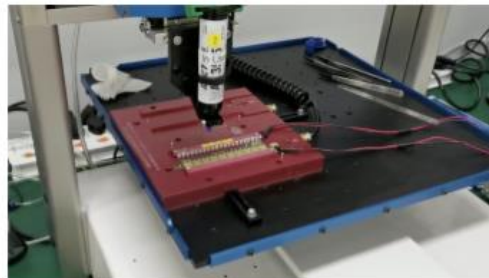
MS sensor + dummy ASICs



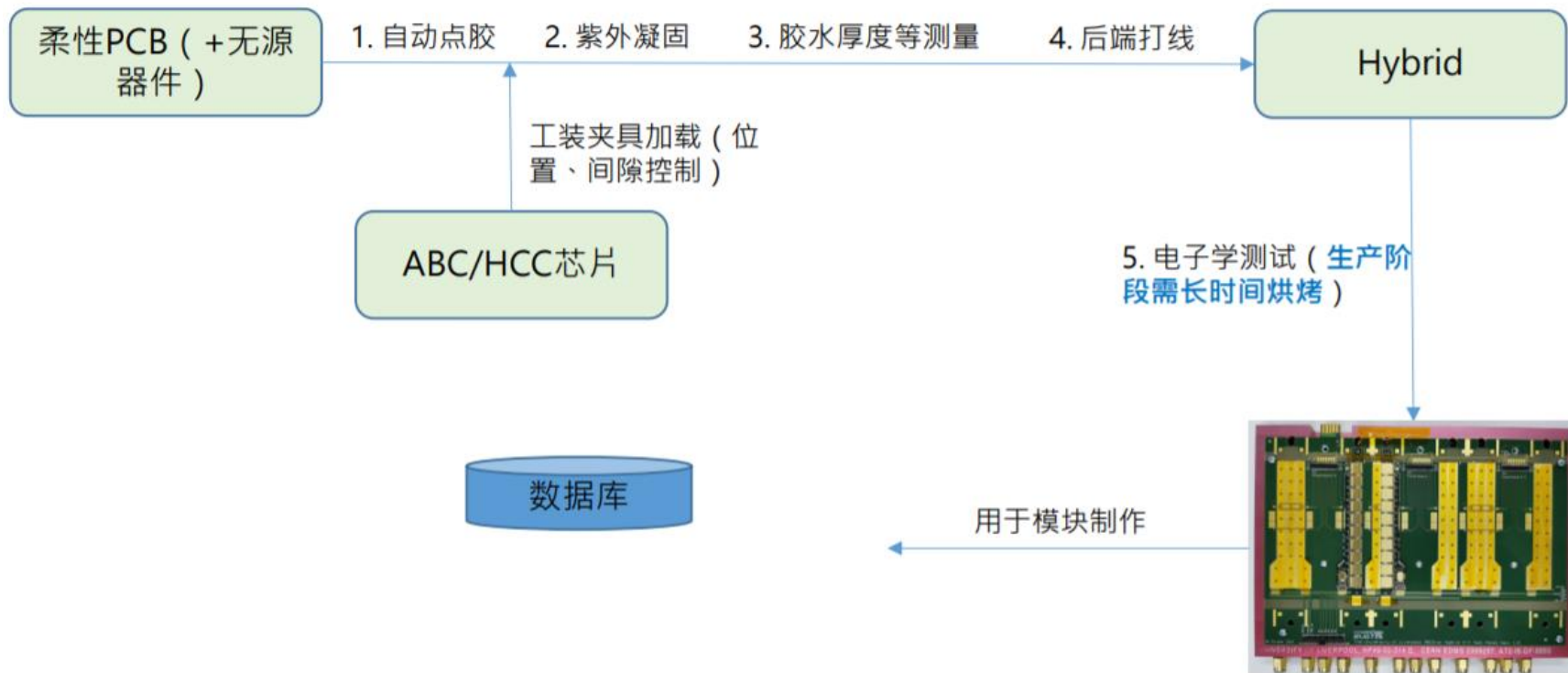
STAR hybrid + ASICs

STAR 模块制作 I

Hybrid 制作主要步骤：

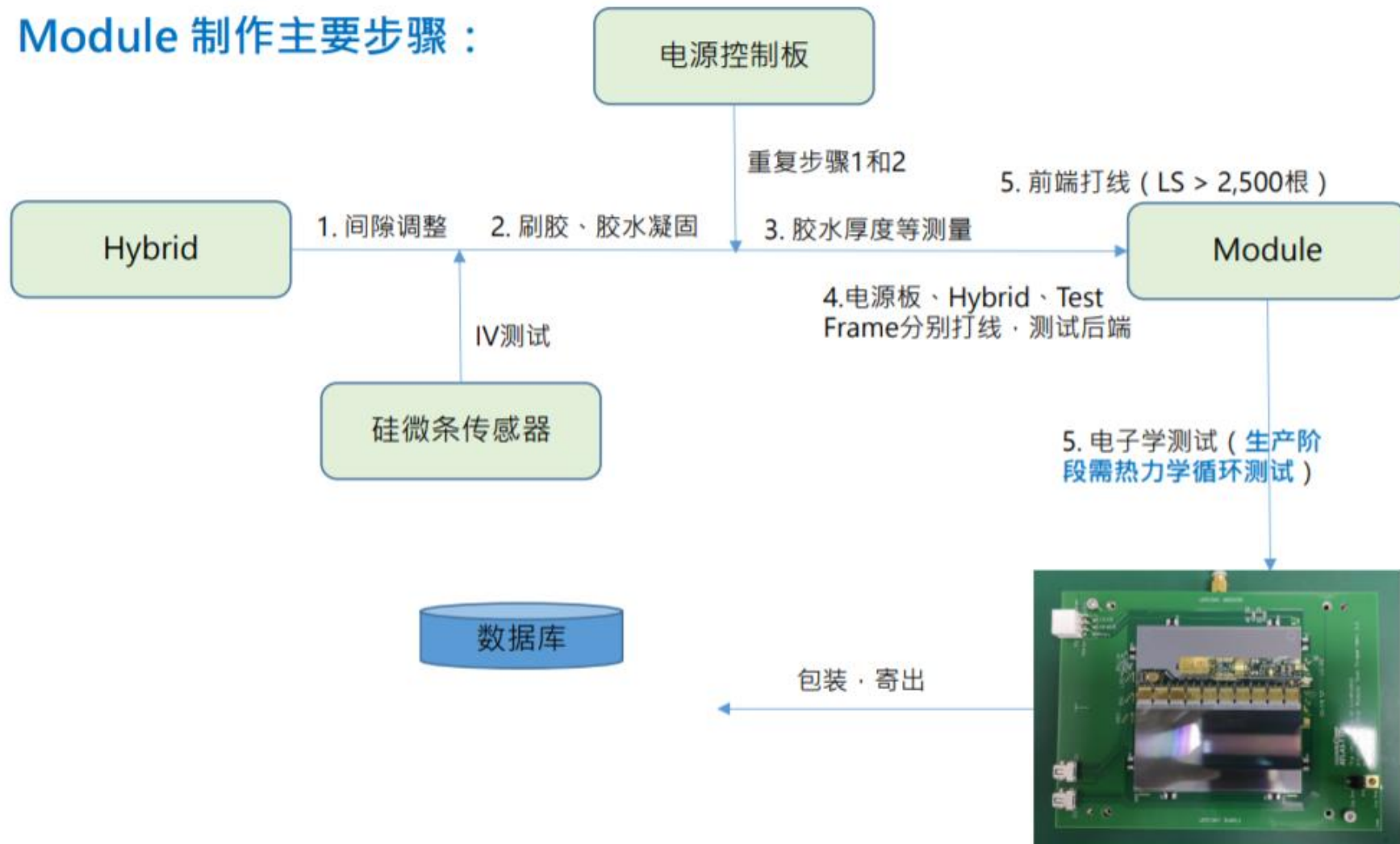


平整度检查



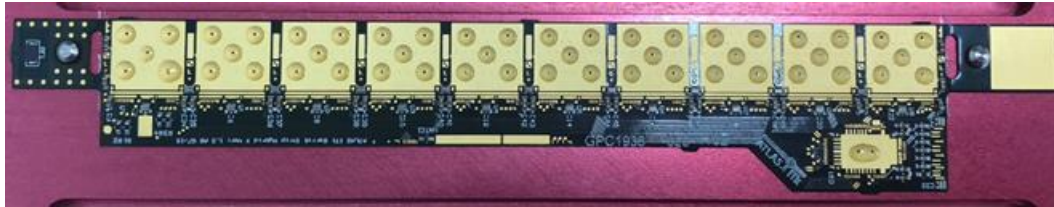
STAR 模块制作 II

Module 制作主要步骤：

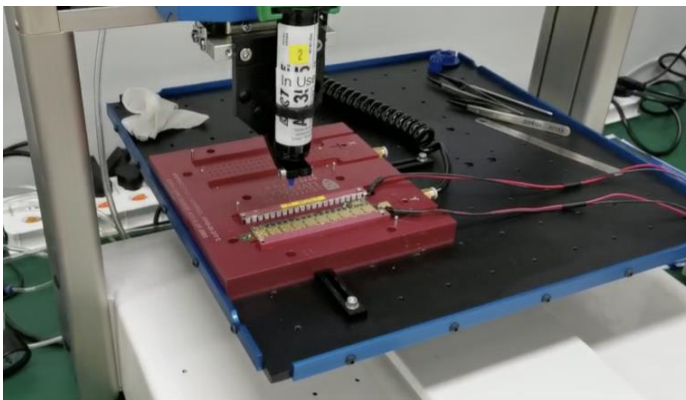


高精度点胶

- 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

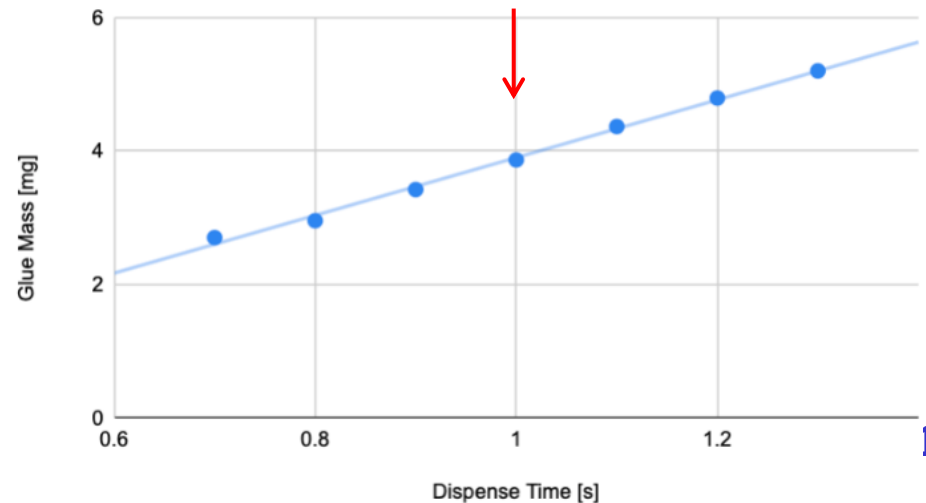


- 自动点胶机



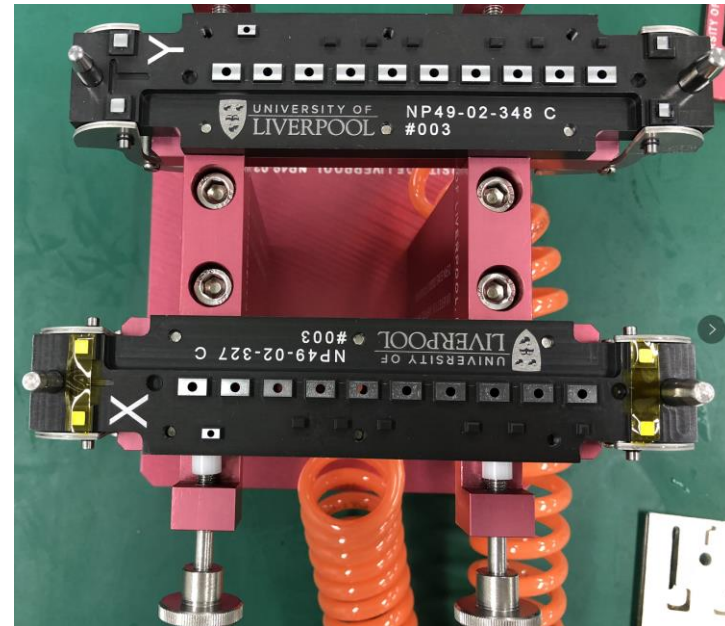
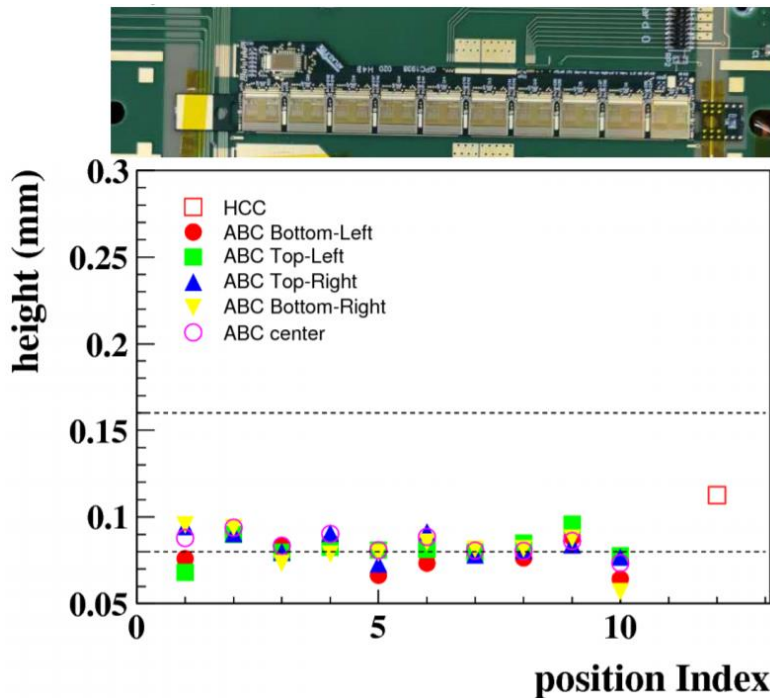
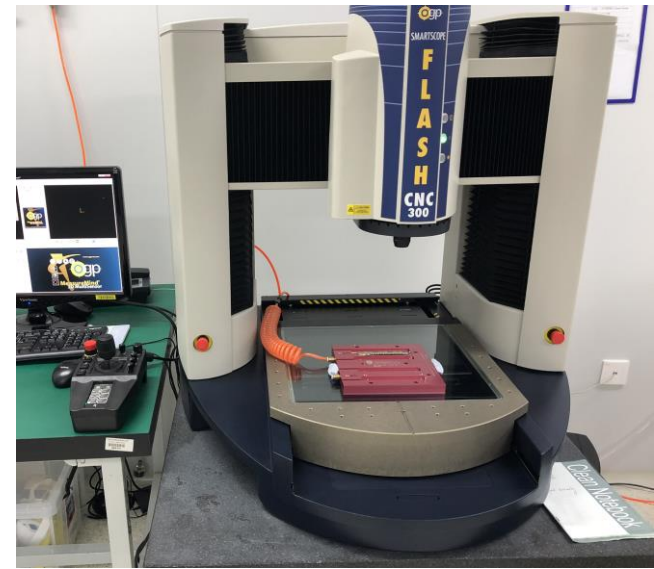
- 刻度胶量~喷胶时间

- 材质、温度依赖



胶水厚度等测量

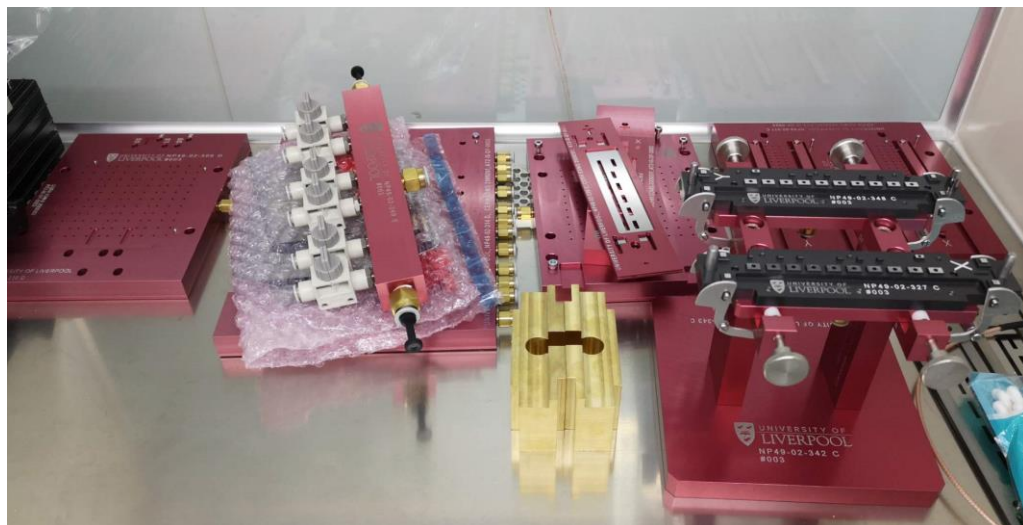
- ✦ 胶水的厚度靠组装工具控制
- ✦ 使用影像仪（SmartScope）激光扫描测量得到芯片与hybrid PCB之间胶水的厚度、hybrid与传感器之间的厚度等等
- ✦ 为正式生产做准备，完善质量控制



提高成品率

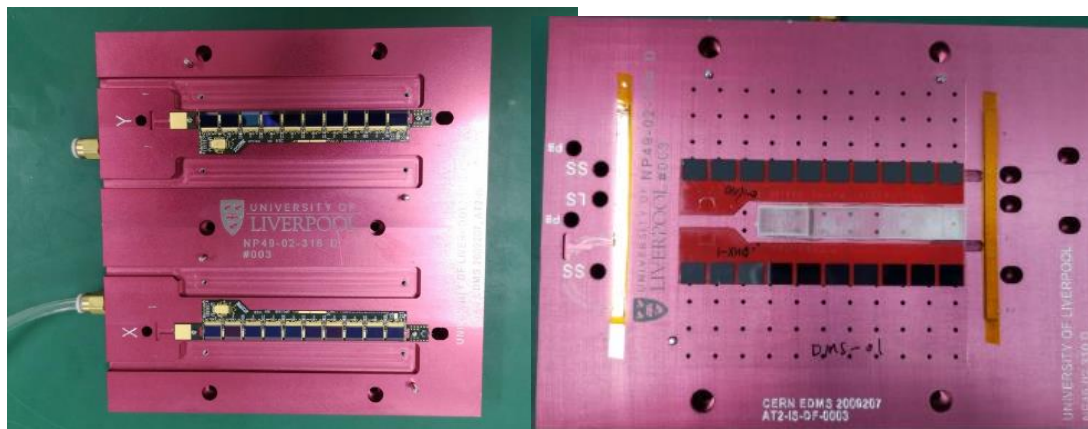
✦ 提高工艺水平，保证生产阶段的成品率

- ✦ 器件本身质量，工具设计，人为操作



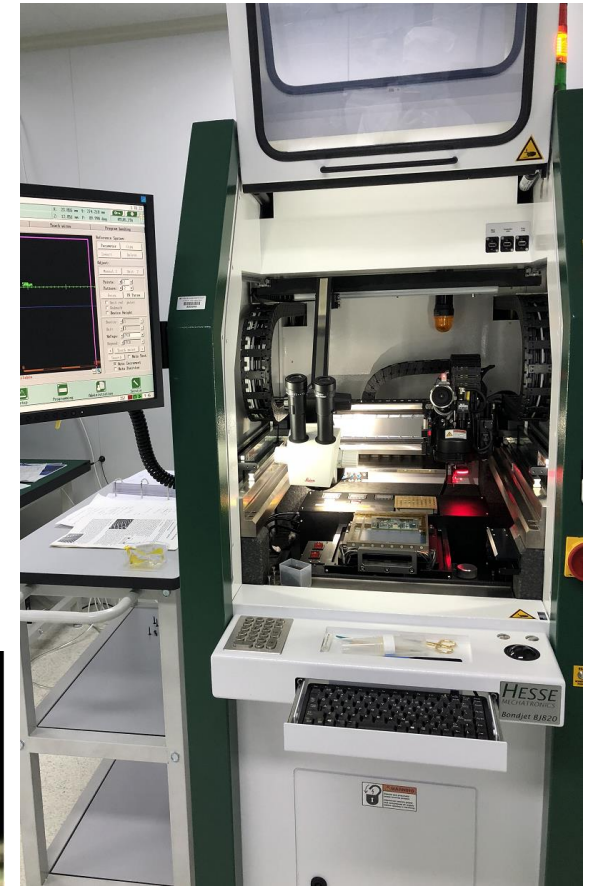
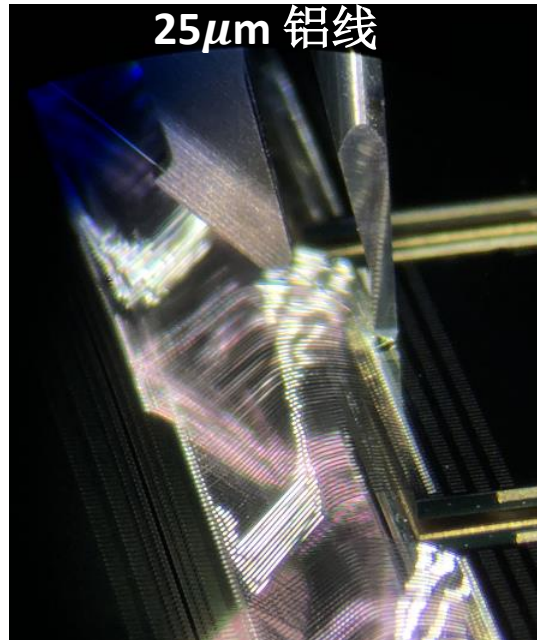
✦ 原型模块建造阶段反复练习

- ✦ 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**



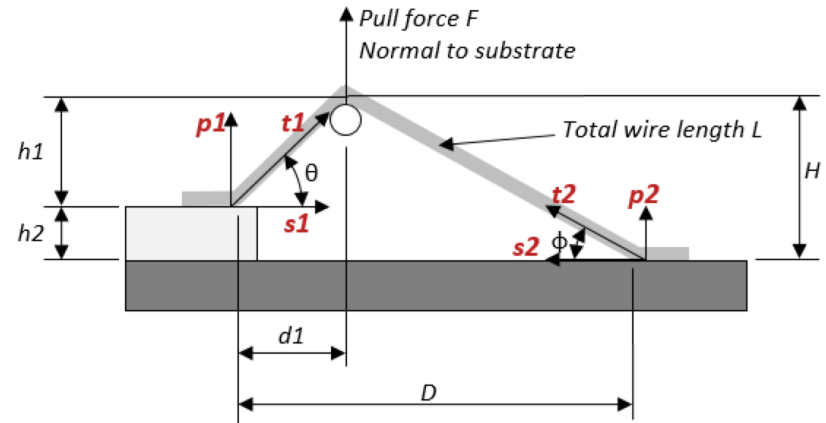
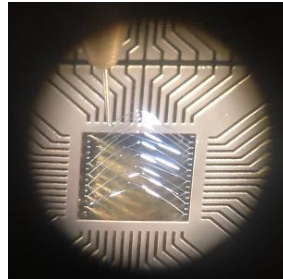
线绑定

- ✦ 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。

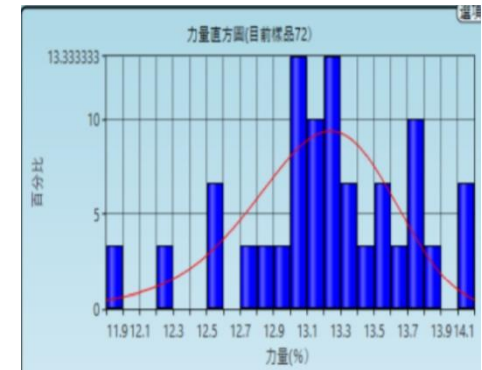
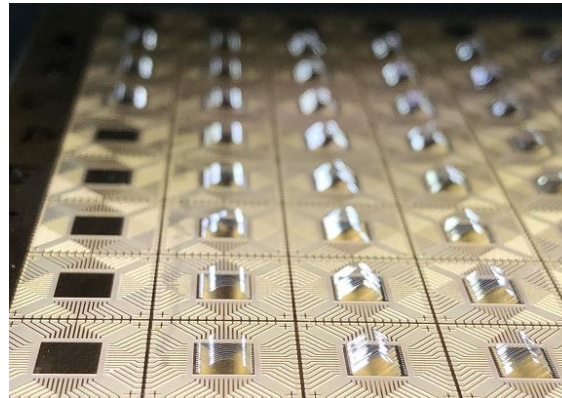


推拉力测试 (刘凯报告)

- 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

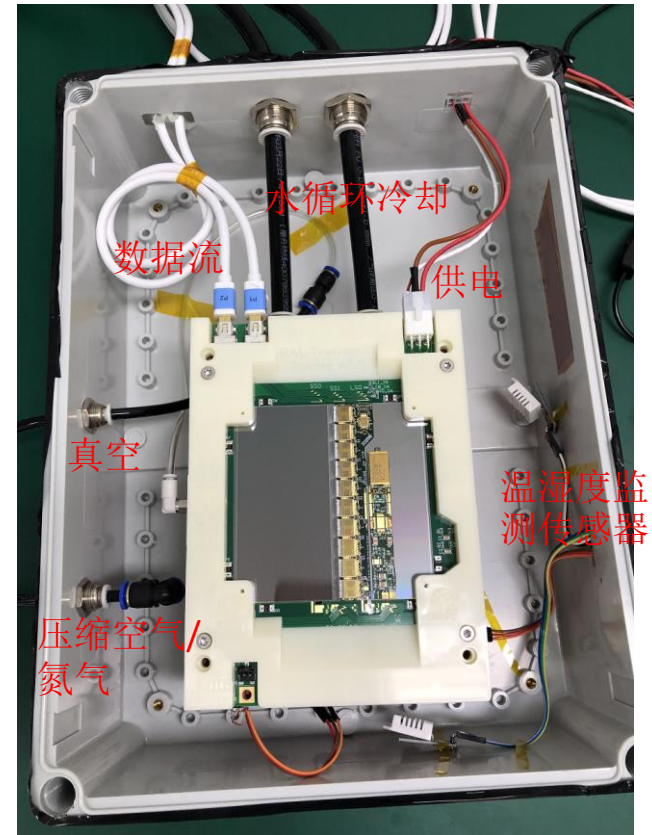
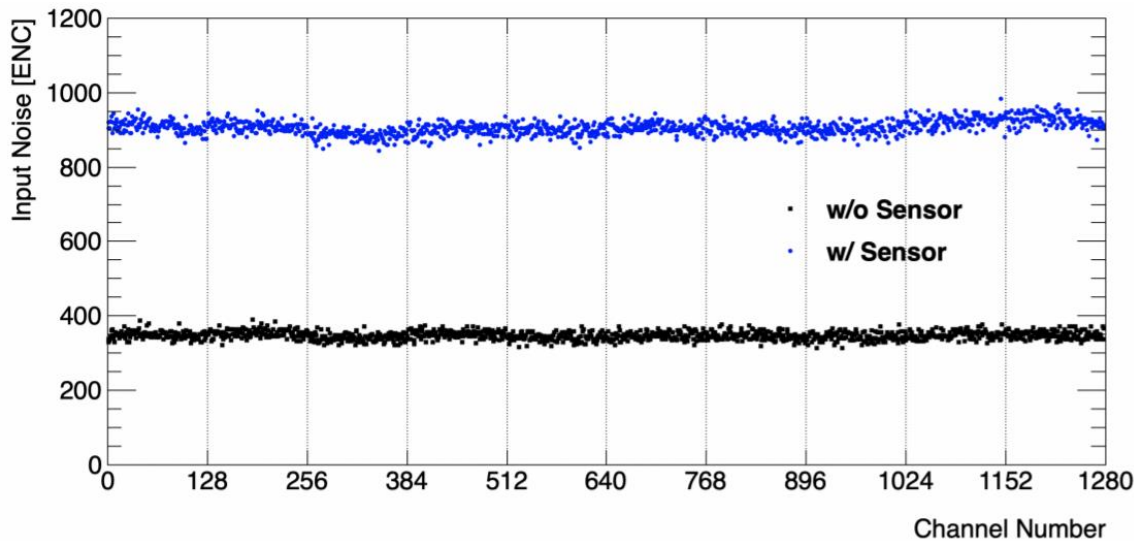


专用练习板



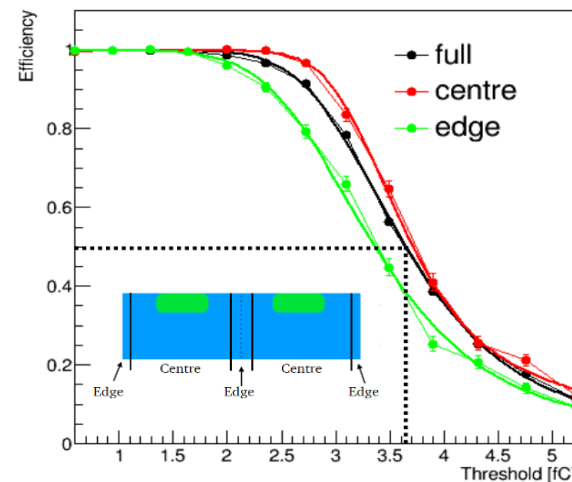
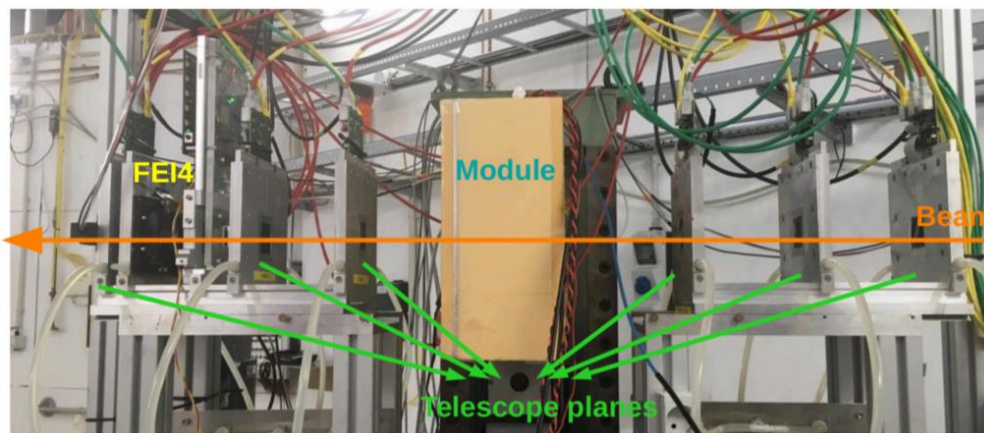
电子学测试（张登峰报告）

- ◆ 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

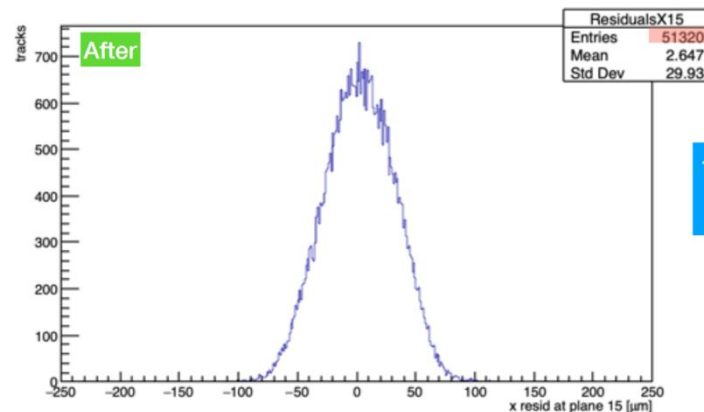


束流测试

- 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)

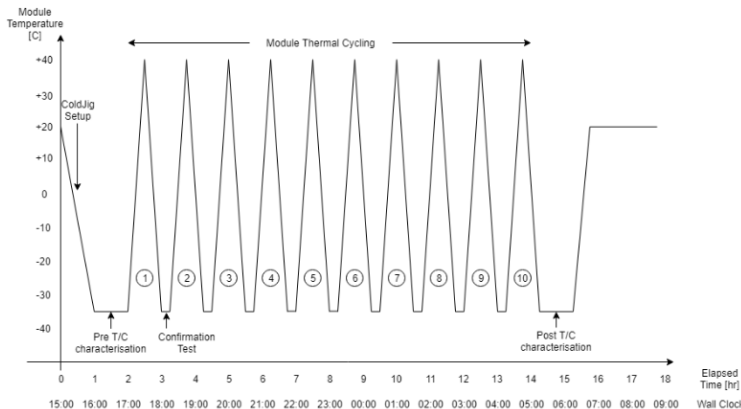
✦ 100 小时 @ 40°C

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°C至 +40°C, 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

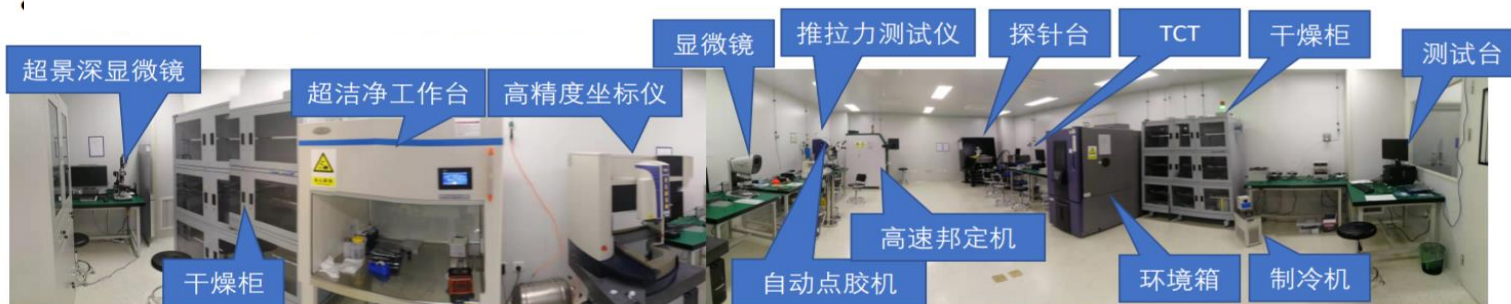
生产点审核准备

Date	Powerboards UK	Powerboards China	UK Hybrids			UK Modules					TOTAL/month	China Hybrids		China Modules		
			B'ham	L'Pool	RAL/IHEP	Bham+Warw	Liv+Shef	Glasgow	Cambridge	RAL		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										
Aug-20		16			18	18										
Sep-20		23			24	24										
Oct-20		10			24	24	6									
Nov-20	v3	35	2		24	24	6									
Dec-20		40	4		20	20	6									
Jan-21	267	40	7		20	20	6									
Feb-21		40	7		20	20	6									
Mar-21		40	8		19	19	6									
Apr-21		40	4		7	7	6									
May-21					3	3	6									
Jun-21					191	191	48									
Jul-21																
Aug-21																
Sep-21																
Oct-21																
Total																

- 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。

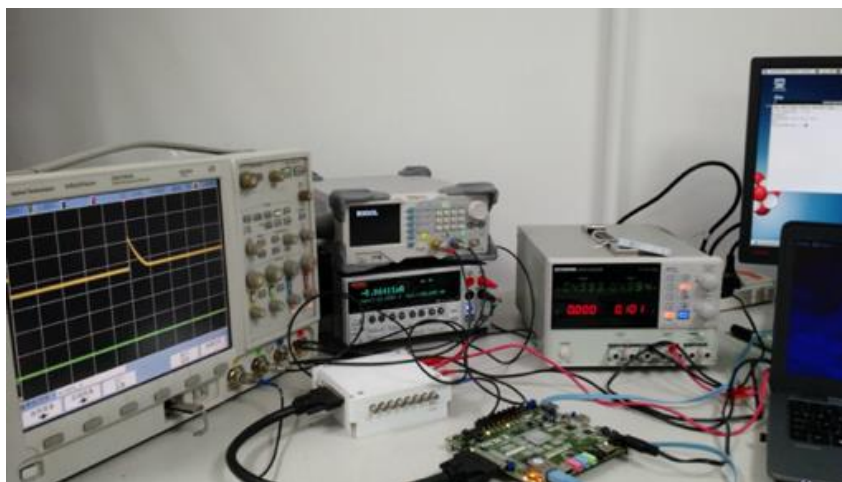


Name	Task	Description	2019	2020		
			FTE	FTE	From	To
Barreiro Guimaraes da Costa, Joao	532954	ITk Strips General Tasks	0.10	0.1	Jan ▾	Jun ▾
Buchanan, Emma	532954	ITk Strips General Tasks	0.67	1	Jan ▾	Jun ▾
Chen, Xin	532954	ITk Strips General Tasks	0.10	0.1	Jan ▾	Jun ▾
Chen, Yebo	532954	ITk Strips General 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 ▾

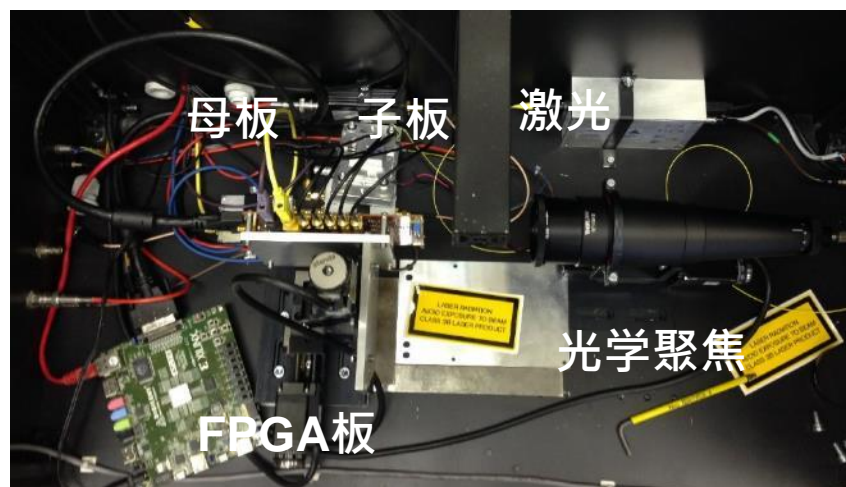
课题三：CMOS 硅微条探测器

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。



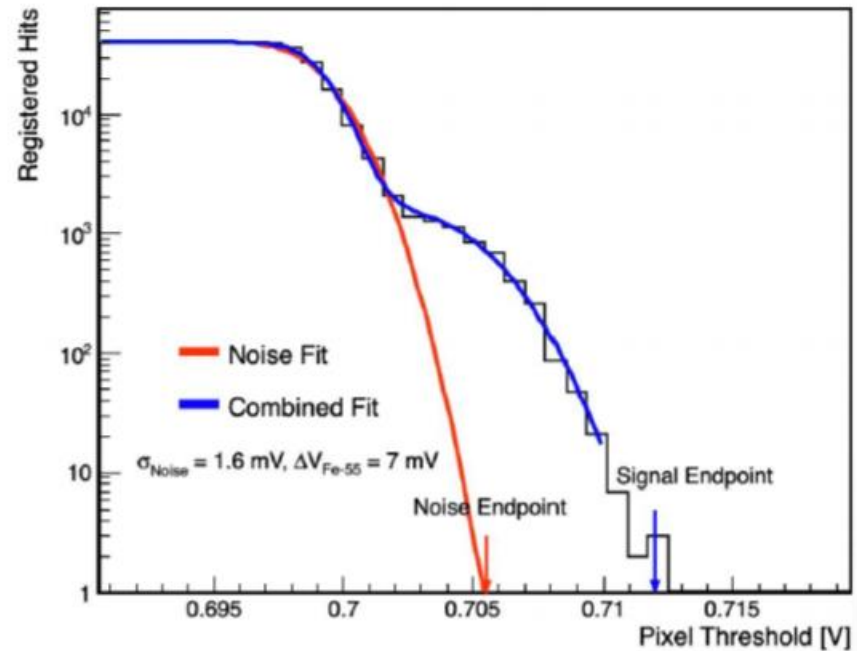
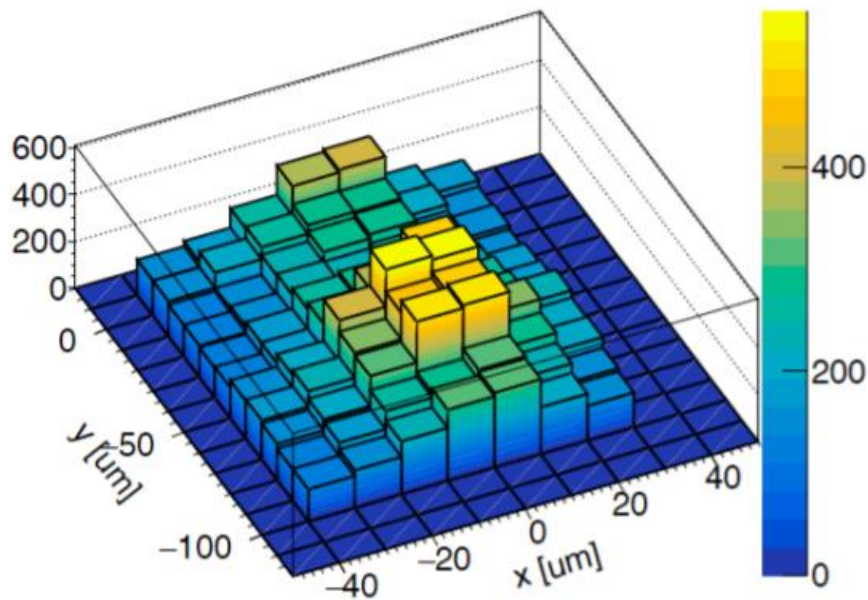
电子学测试系统



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

Testbeam studies of barrel and end-cap modules for the ATLAS ITk strip detector before and after irradiation Version 0.3

F. Rühra^a, A. Affolder^b,
Becot^b, B. Bruers^d, E. Bus
David¹, S. Diez Cornell
Garcia Argos^a, A. Green
Hauser^a, J. Keller^b, D. I
Kroll¹, M. Liberatore
Milovanovic¹, M. Minano
M. Quetsch-Maitland²,
Rodriguez^a, E. Rossi^d,
Thomas^a, C. Wiglesworth

^aPhysikalisches Institut, A
^bSanta Cruz Institute for Part
^cIHEP - Beijing Institute of
^dDeutsches Elektronen-
¹Institut für Physik,
²Charles University, Facu
³Department of Phy
⁴SUPA - School of Physics

⁵Department of Physics a
⁶Department of Physi
⁷Instituto de Física Corpuscu
⁸Particle Physics Department,
⁹Oliver Lodge Laborator
¹⁰Department of Physics, A
¹¹T
¹²Department of Ph
¹³Cambridge Laboratory, A
¹⁴Institute of Physics of B
¹⁵Experimentelle Physik IV,
¹⁶Department of Theoretic
¹⁷School of Physics and Ast

¹⁸Niels Bohr Institute,

ATLAS17LS – a large-format prototype silicon strip sensor for long-strip barrel section of ATLAS ITk strip detector

Y. Unno^{18,a}, Y. Abo¹⁸, A. Affolder^b, P. Allport^d, I. Bloch¹, A.
C. Haber¹, K. Hara¹, B. Hommels¹⁹, S. Kamada²⁰, T. Kotfas²¹, I
M. Ullian²², K. Yamazaki

¹⁸School of Physics and Astronomy, University of Birmingham
¹⁹Cambridge Laboratory, University of Cambridge, JJ Thomson
²⁰Physics Department, Carleton University, 1125 Colonel
²¹Centro Nacional de Microelectrónica (IMB-CNM, CSIC), I
²²DESY Zeuthen, Plattenstraße 6,
²³School of Physics and Astronomy, the University of Glasgow,
²⁴Solid State Division, Hamamatsu Photonics K.K., 1206-1 Ichino-1
²⁵Institute für Physik, Humboldt-Universität zu Berlin
²⁶Institute of High Energy Physics (IHEP) and the Chinese Academy
²⁷Institute of Particle and Nuclear Study, High Energy Accelerator Research
²⁸Lawrence Berkeley National Laboratory, Cyclotron
²⁹Queen Mary University of London, Mile End, London
³⁰Particle Physics Department, STFC Rutherford Appleton Laboratory, Didcot
³¹Santa Cruz Institute for Particle Physics (SCIPP), Santa Cruz
³²Institute of Pure and Applied Sciences, University of Tsukuba

Abstract

The ATLAS experiment is going to replace the current ITk ATLAS detector for HL-LHC at CERN. Silicon strip detector sections. We have designed and fabricated a prototype single outer barrel layer with long strips (LS), ATLAS17LS. It has a dimension of 9.80 (width) x 9.76 (length) cm². The sensor length, a strip pitch of 75.5 μm, and a slim edge design. We have tested it up to 1000 V, with a good signal collection after the irradiation.

We had two purposes in the ATLAS17LS fabrication: to provide a quantity of the sensors for prototyping the detector and to provide a quantity of the sensors for prototyping the detector. We had two purposes in the ATLAS17LS fabrication: to provide a quantity of the sensors for prototyping the detector and to provide a quantity of the sensors for prototyping the detector. We had two purposes in the ATLAS17LS fabrication: to provide a quantity of the sensors for prototyping the detector and to provide a quantity of the sensors for prototyping the detector.

*Corresponding author. e-mail: f.ruehra@cern.ch

Preprint submitted to Journal of Instrumentation

Study of CMOS strip sensor for future silicon tracker

Y. Han^{1,2,3,*}, H. Zhu^{1,2,3,*}, A. Affolder⁴, K. Arndt⁵, R. Bates⁶, M. Benoit⁷, F. D. Bello⁸, A. Blue⁹, D. Bortoletto¹⁰, M. Buckland^{11,12}, C. Buttar¹³, P. Caragiulo¹⁴, Chen¹⁵, D. Das¹⁶, D. Doering¹⁷, J. Dopke¹⁸, A. Dragone¹⁹, F. Ehrler²⁰, V. Fadeyev²¹, W. Fedoriko²², Z. Galloway²³, C. Gay²⁴, H. Grabau²⁵, I. M. Gregor²⁶, J. Grenier²⁷, A. Grillo²⁸, B. Hiti²⁹, M. Hoferkamp³⁰, L. B. A. Hommels³¹, T. Huffman³², J. John³³, K. Kanisavlasevic³⁴, C. Kenney³⁵, G. Kramerberger³⁶, P. Liu³⁷, W. Lu³⁸, Z. Liang³⁹, J. Mandl⁴⁰, D. Manenke⁴¹, F. Martinez-Mekineci⁴², S. McMahon⁴³, L. Meng⁴⁴, M. Mikuz⁴⁵, D. Muenstermann⁴⁶, R. Nickerson⁴⁷, I. Peric⁴⁸, P. Phillips⁴⁹, R. Plackett⁵⁰, F. Rubbo⁵¹, L. Ruckman⁵², J. Segal⁵³, Seidel⁵⁴, A. Seiden⁵⁵, L. Shipsey⁵⁶, W. Song⁵⁷, M. Stantitzki⁵⁸, D. Su⁵⁹, C. Tamm⁶⁰, R. Turchetta⁶¹, L. Viganò⁶², J. Volk⁶³, R. Wang⁶⁴, M. Warren⁶⁵, F. Wilson⁶⁶, S. Worm⁶⁷, Q. Xin⁶⁸, J. Zhang⁶⁹

¹University of Liverpool, United Kingdom
²University of Oxford, United Kingdom
³SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
⁴University of Geneva, Switzerland
⁵CERN, European Center for Nuclear Research, Switzerland
⁶SLAC National Accelerator Laboratory, United States
⁷Rutherford Appleton Laboratory, Didcot, United Kingdom
⁸Karlsruhe Institute of Technology, Germany
⁹University of California Santa Cruz, Santa Cruz Institute for Particle Physics, United States
¹⁰Deutsches Elektronen-Synchrotron, Germany
¹¹University of New Mexico, United States
¹²Cambridge University, United Kingdom
¹³Jozef Stefan Institute, Ljubljana, Slovenia
¹⁴University of Ljubljana, Slovenia
¹⁵Lancaster University, United Kingdom
¹⁶Argonne National Laboratory, United States
¹⁷University College, London, United Kingdom
¹⁸Institute of High Energy Physics, Beijing, China
¹⁹University of British Columbia, Canada
²⁰University of Chinese Academy of Sciences, Beijing, China
²¹State Key Laboratory of Particle Detection and Electronics, Beijing, China

Abstract

The development of commercial High-Voltage CMOS processing technology allowing the combination of sensing element and signal processing circuitry on one single chip, became an exciting method considered for charged particle tracking in High Energy Physics experiments. Larger and deeper depletion

*Corresponding author
E-mail: yhan@liverpool.ac.uk, hzhu@liverpool.ac.uk (Y. Han)

March 14, 2020

The ABC130 barrel module prototyping programme for the ATLAS strip tracker

Luise Poley^a, Craig Sawyer^b, Sagar Addepalli^a, Anthony Affolder^c, Nedaa Alexandre Asbah^d, Bruno Allongue^e, Phil Allport^f, Eric Anderssen^g, Francis Anghinolfi^h, Jean-Francois Arguin^{im}, Jan-Hendrik Arling^{ab}, Olivier Arnaez^{af}, Joe Ashby^f, Eleni Myrto Asimakopoulou^{an}, Naim Bora Atlay^{ai}, Ludwig Bartsch^c, Matthew J. Basso^{af}, Scott L. Beaupre^{ah}, Graham Beck^q, Carl Beichert^{mi}, Laura Bergstenⁿ, Jose Bernabeu^{aj}, Prajita Bhattarai^{io}, Ingo Bloch^{ab}, Andrew Blue^f, Michal Bochenek^d, James Botte^{ad}, Liam Boyntonⁱ, Richard Brenner^{am}, Ben Brueres^{ab}, Emma Buchanan^{w,x}, Brendon Bullard^{im}, Francesca Capocasa^o, Isabel Carr^{af}, Sonia Carra^{ab}, Chen Wen Chao^{am}, Jiayi Chen^{al}, Liejian Chen^{w,x,y}, Yebo Chen^{w,x,y}, Xin Chen^z, Vladimir Cindro^{al}, Alessandra Ciocci^a, Jose V. Civera^{aj}, Kyle Cormier^{ad}, Ben Crick^z, Wladyslaw Dabrowski^{io}, Mogens Dam^{ao}, Joel de Witt^c, Gabriel Demontigny^{am}, Karola Dette^{af}, Sergio Diez^{ab}, Fred Doherty^f, Nandor Dressnandt^d, Sam Edwards^{af}, Vitaliy Fadeyev^c, Sinead Farringtonⁱ, William Fawcett^h, Javier Fernandez-Tejero^a, Emily Filmer^{am}, Celeste Fleta^a, Bruce Gallop^h, Zachary Galloway^c, Carlos Garcia Argos^{ac}, Matthew Gignac^c, Dag Gillberg^{ad}, James Glover^a, Peter Goettlicher^{ah}, Laura Gonella^a, Andrej Gorišek^{ad}, Charles Grant^{ae}, Fiona Grant^f, Calum Gray^f, Ashley Greenallⁱ, Ingrid-Maria Gregor^{ab}, Graham Greig^{ah}, Shan Gu^b, Francesco Guescini^{im}, Joao Barreiro Guimaraes da Costa^{w,x}, Jane Gunnell^f, Ruchi Gupta^{ab}, Carl Haber^a, Amogh Halgheri^d, Tom-Erik Haugen^a, Marc Hauser^{ac}, Sarah Heim^{ab}, Timon Heim^a, Cole Helling^c, Hannah Herde^h, Nigel P. Hessey^{af}, Bart Hommels^h, Jan Cedric Hönig^{ac}, Amelia Hunter^a, Paul Jackson^{am}, Keith Jewkesⁱ, Thomas Allan Johnson^a, Tim Jones^z, Nathan Kang^a, Jan Kaplon^z, Mohammad Kareem^{at}, Paul Keener^d, John Keller^{ad}, Michelle Key-Charriere^b, Samer Kilani^o, Dylan Kisiuk^{af}, Christoph Thomas Klein^h, Thomas Koffas^{ad}, Gregor Kramerberger^{al}, Karol Krizka^a, Jiri Kroll^{ak}, Susanne Kuehn^{ac}, Matthew Kurth^{w,x,y}, Charilou Labitan^{ab}, Carlos Lacasta^{ad}, Heiko Lacker^{al}, Pablo León^{aj}, Boyang Li^z, Yiming Li^{w,x}, Zhiying Li^{pe}, Zhijun Liang^{w,x}, Marianna Liberatore^{ab}, Alison Lister^{ap}, Kai Liu^{w,x}, Peilian Liu^{w,x}, Thomas Lohse^{al}, Jonas Lönker^{am}, Xinchou Lou^{w,x,y}, Weiguo Lu^{w,x}, David Lynn^j, Sven Mädfegessel^{ac}, Kambiz

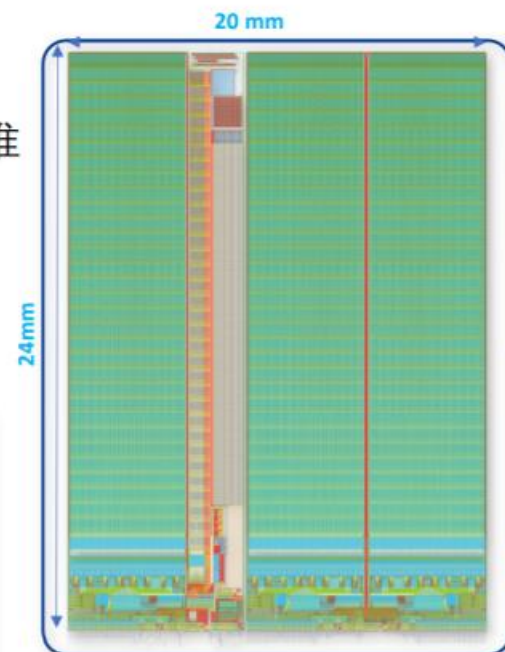
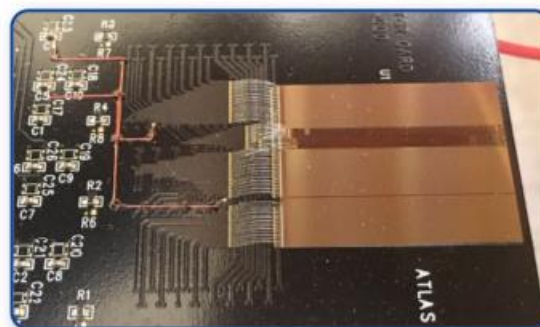
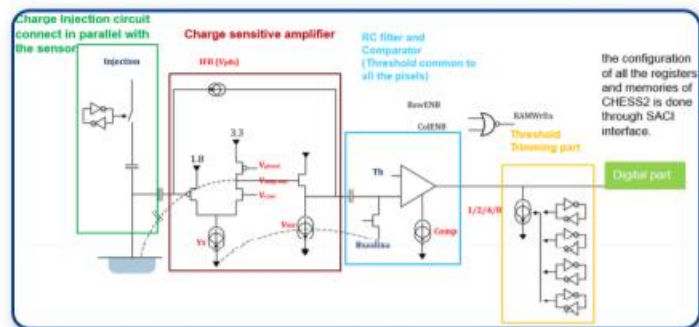
小结与展望

- ✦ 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

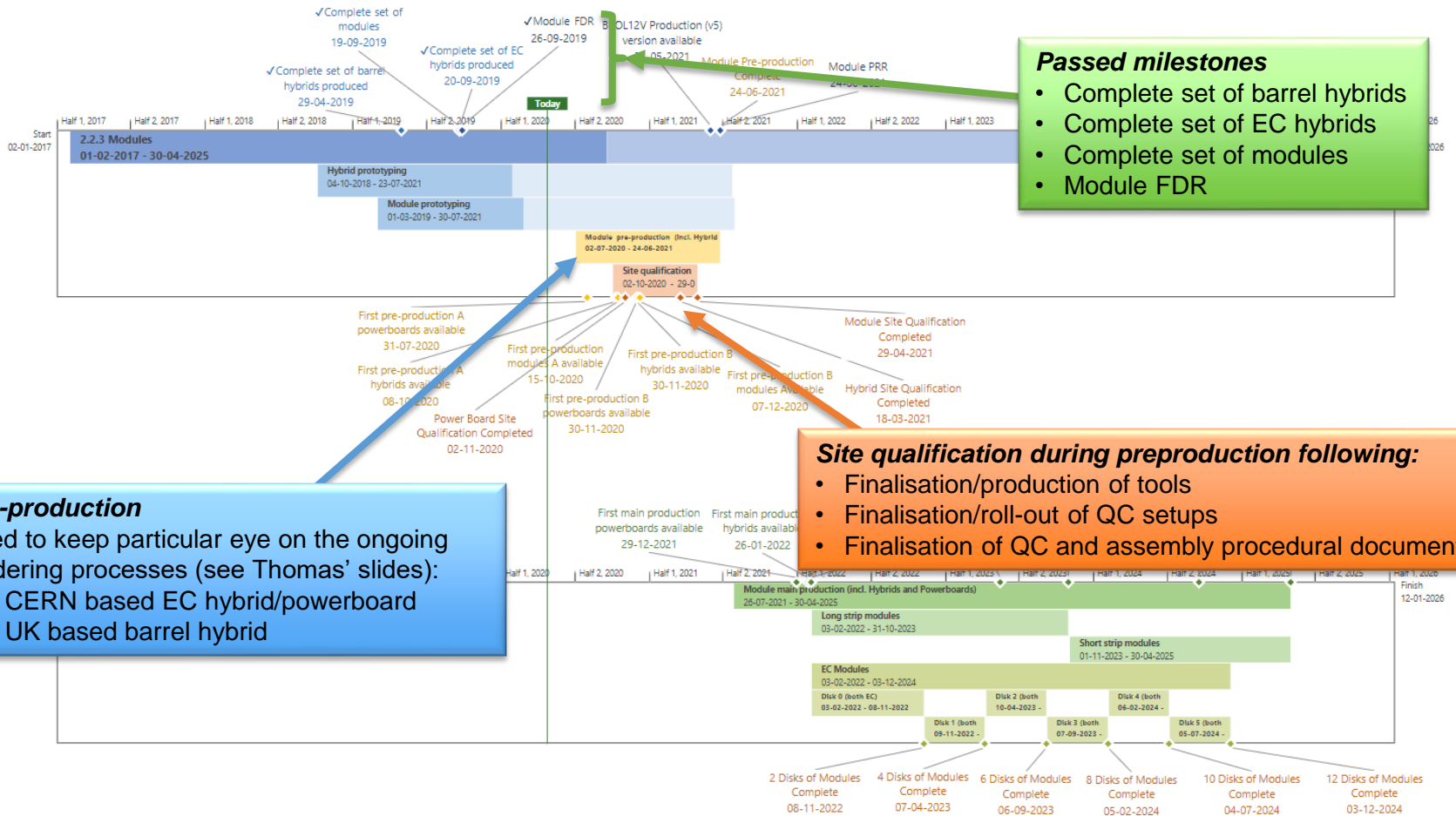
课题三：CMOS硅微条探测器性能测试

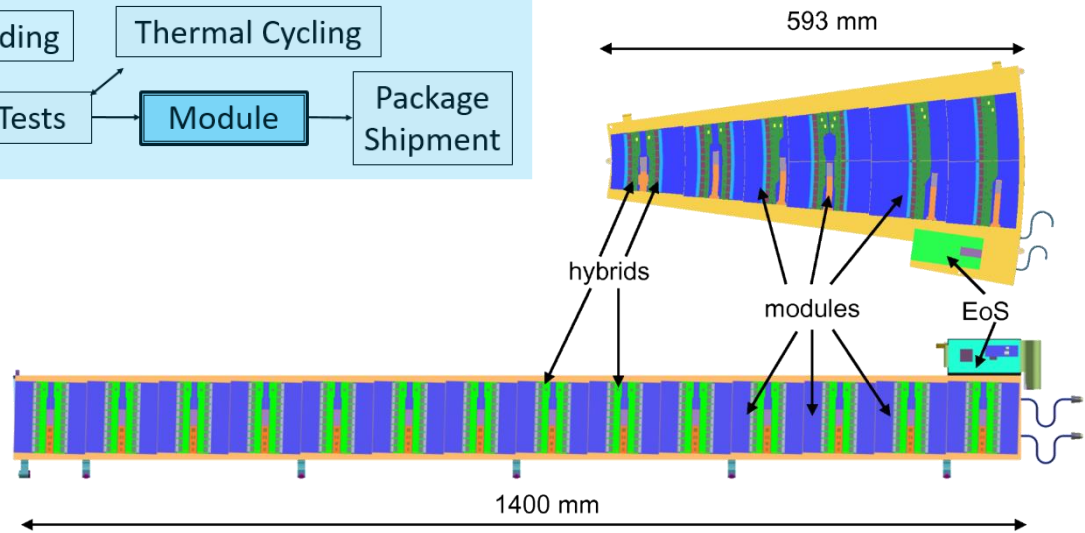
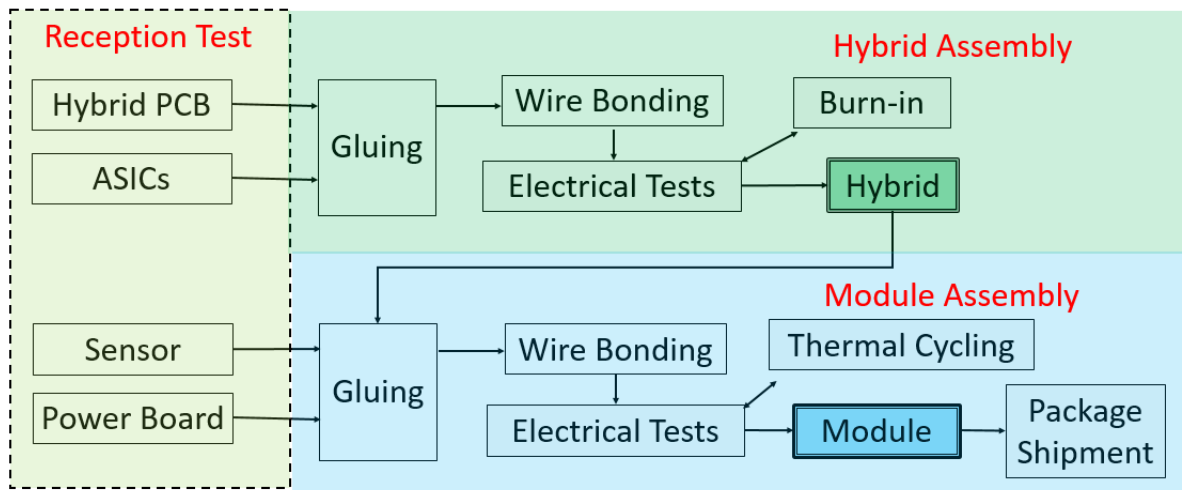
- 基于先期研制的CMOS硅微条传感器，开展主要性能测试（电荷收集效率、噪声水平、空间分辨率等）
- 测试结果用于改进传感器设计，并为集成的读出电子学设计提供参考基准
- 基于FPGA开发CMOS硅微条传感器的数字读出芯片，构建原理样机
- 通过实验室放射源和试验线束完成性能标定



与SLAC/UCSC 合作

WBS 2.2.3: Modules – Schedule Overview



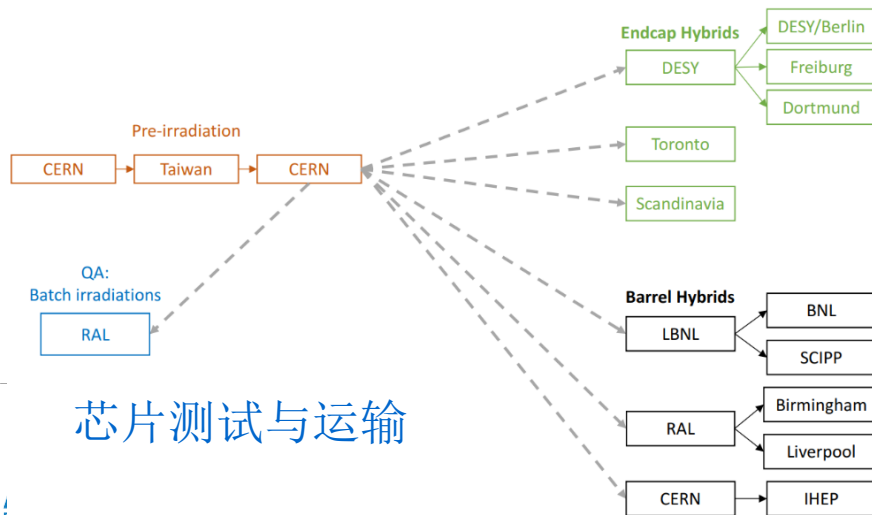


Irradiations at INER

- 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

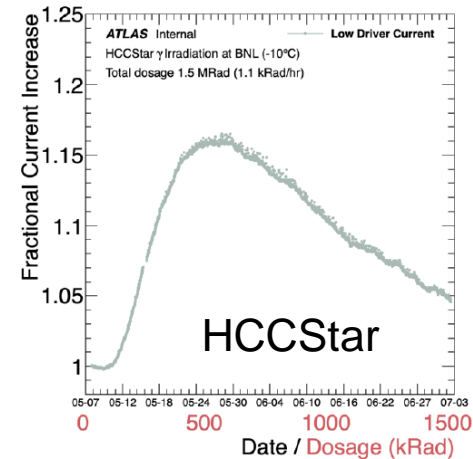
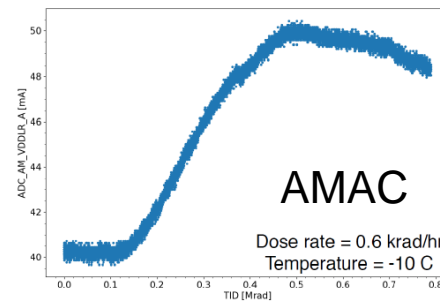
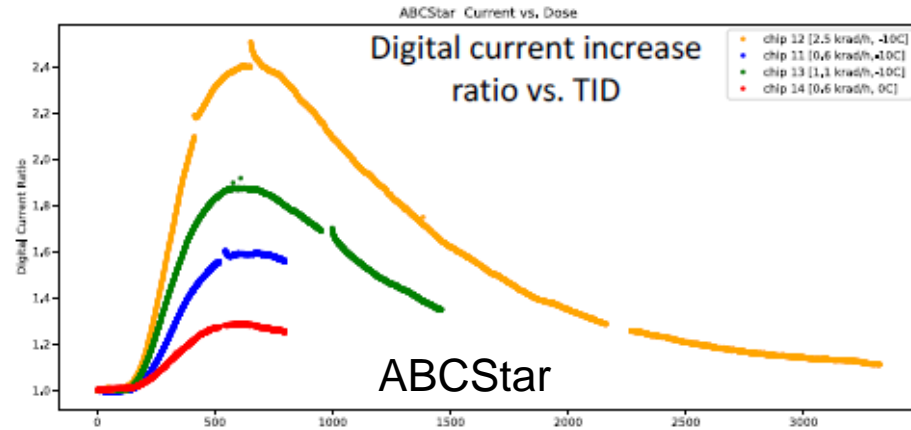


芯片测试与运输

Test results: irradiation at low dose rate

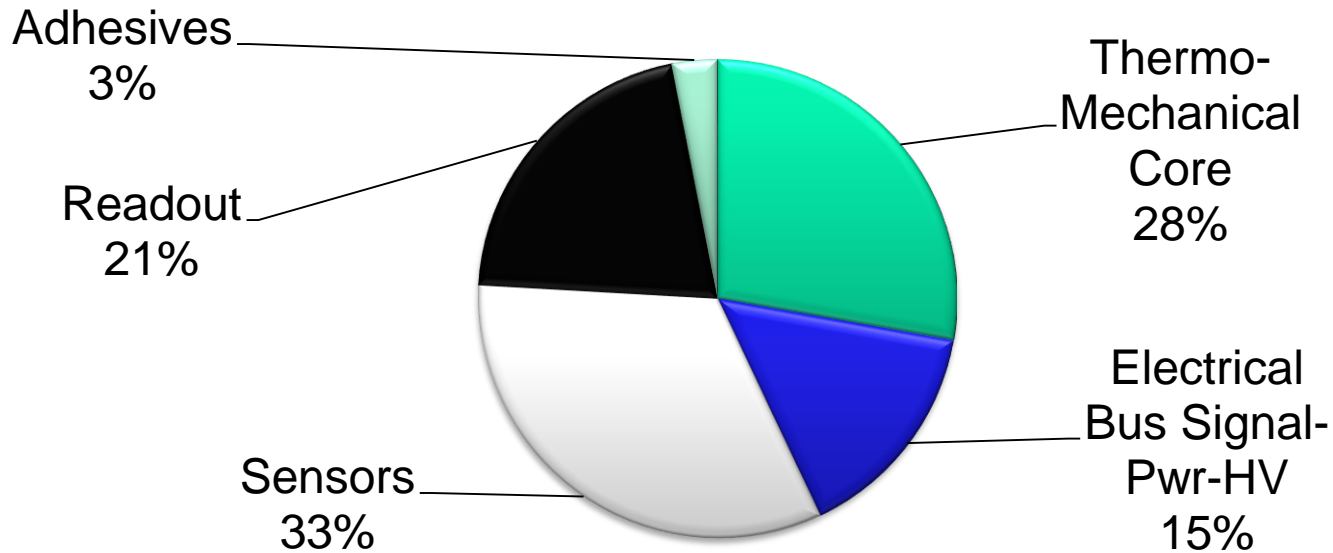
- One-off tests on prototype and pre-production ASICS
 - BNL gamma ray source
- Low temperature, low dose rate irradiation to reproduce experimental conditions
- Results for ABCstar consistent with ABC130
 - Feed into thermal-power model of Strips

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

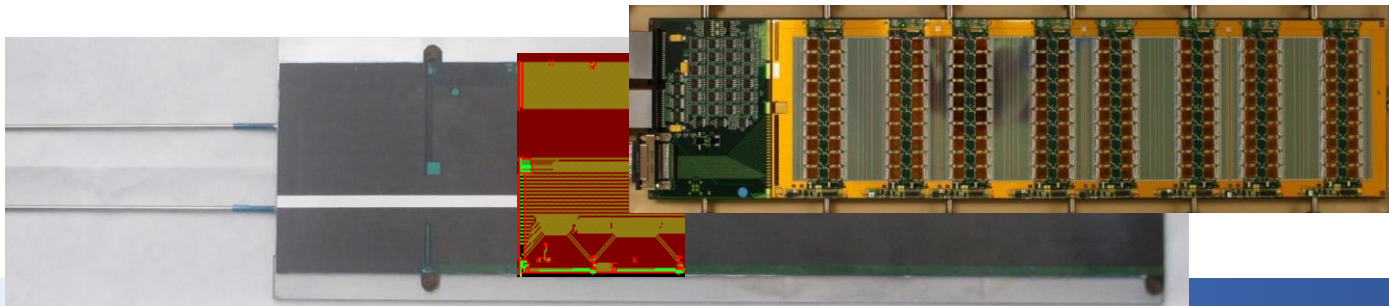


A Low Mass Structure

Contributions to Radiation Length



- Total material/stave is in the range 2.0-2.5% X_0

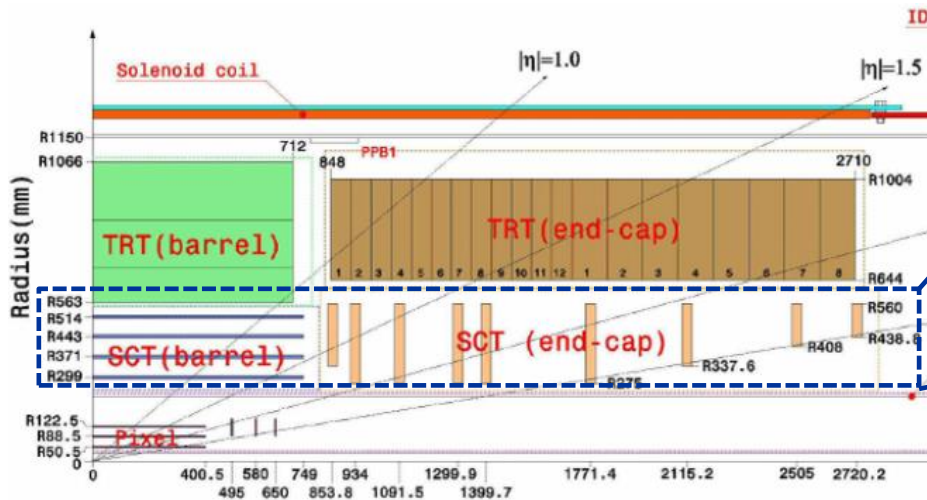


Scale

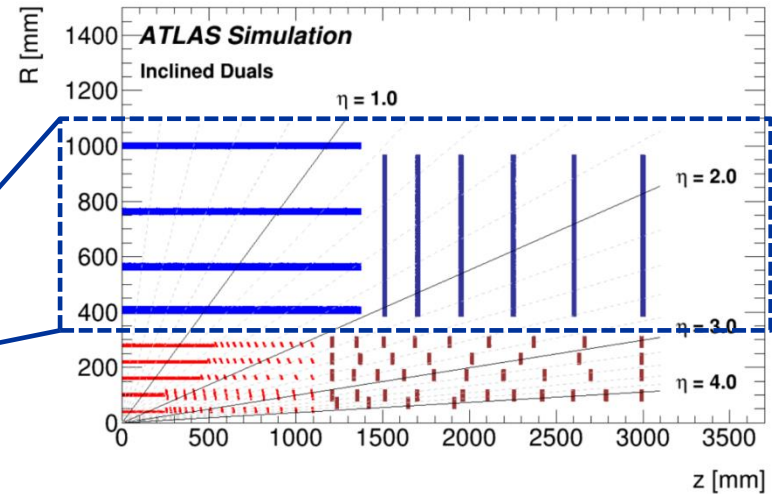
- 163 m² of silicon
- 233,856 FE ASICs
- 17,888 modules
- 392 staves
- 384 petals
- ~\$60M in “CORE” units
- ~\$225M in USA units (labor and inflation included)

ATLAS ITk Layout (from TDR)

Current



Future



- High-granularity
- Radiation-hard
- Extended coverage to η of 4
($|\eta| < 2.5$ for Run 2)

- 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

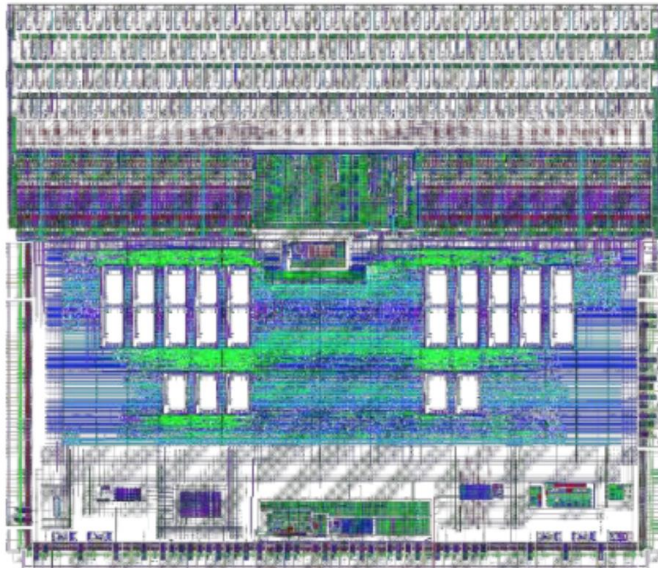
$$\eta = -\ln \tan\left(\frac{\theta}{2}\right)$$

ABCStar: improving SEE protection

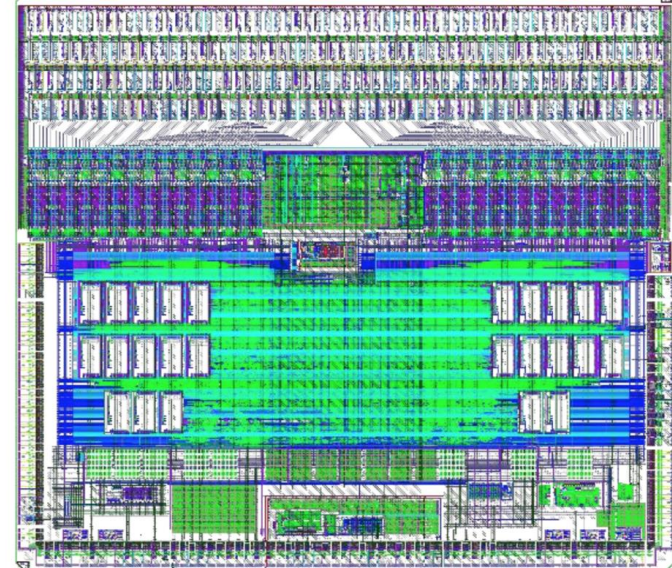
We decided to add full triplication to the ABCStar design, including clocks and resets, using CERN's TMRG tool: systematic, widely used at CERN.

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

Prototype ABCStar

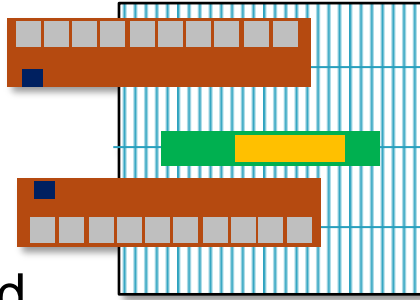


Pre-production ABCStar

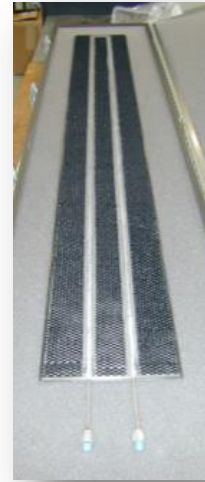


Barrel Modules and Staves

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



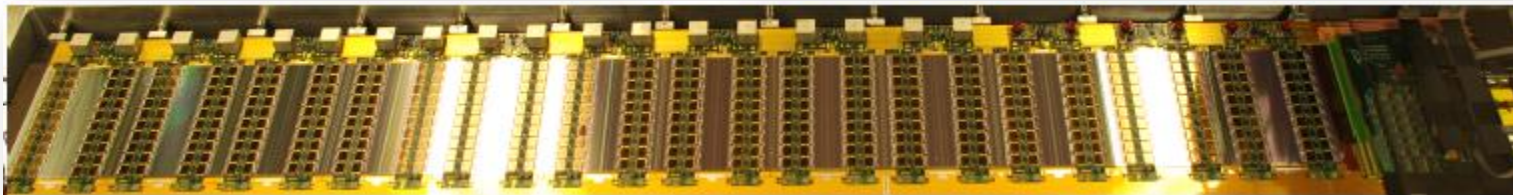
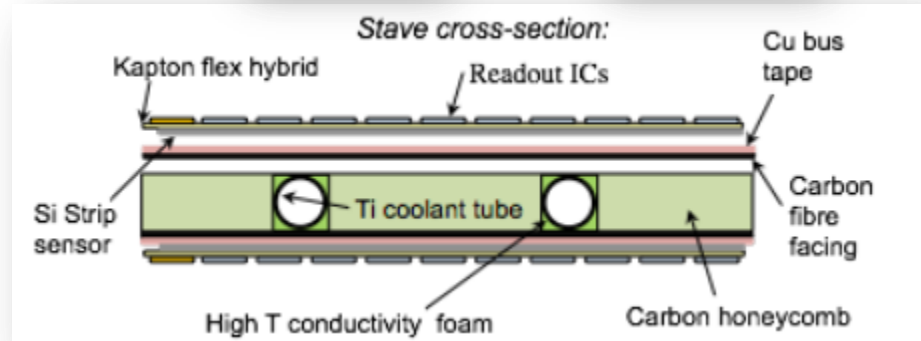
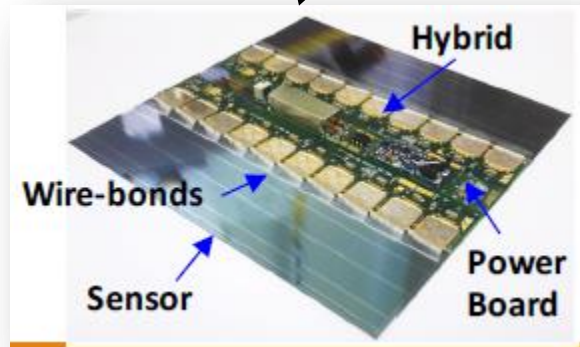
x 28 +



+



=




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	PMMMA 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。

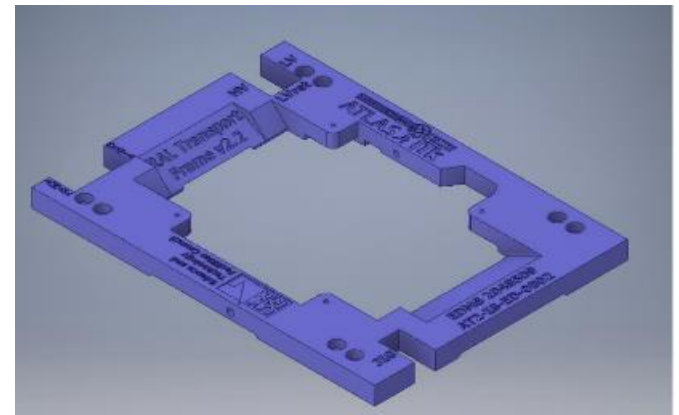
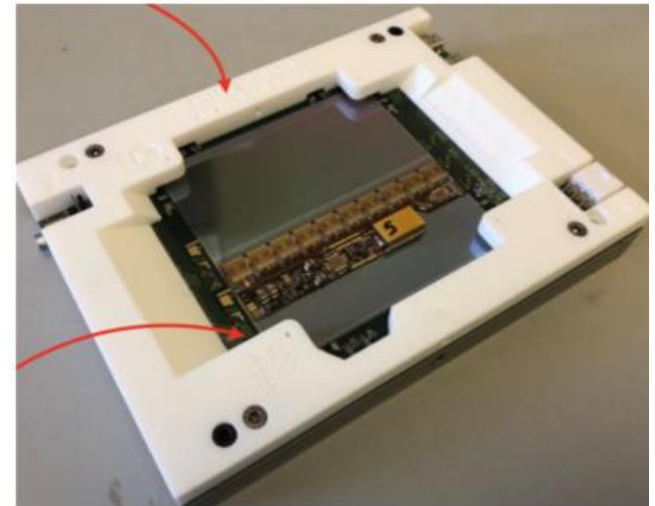
北京瑞隆祥模具有限公司 Beijing Relontion Mould Co., Ltd

王晓华

TEL: 010-89774572 FAX: 010-89774572

MOBILE: 13683053196

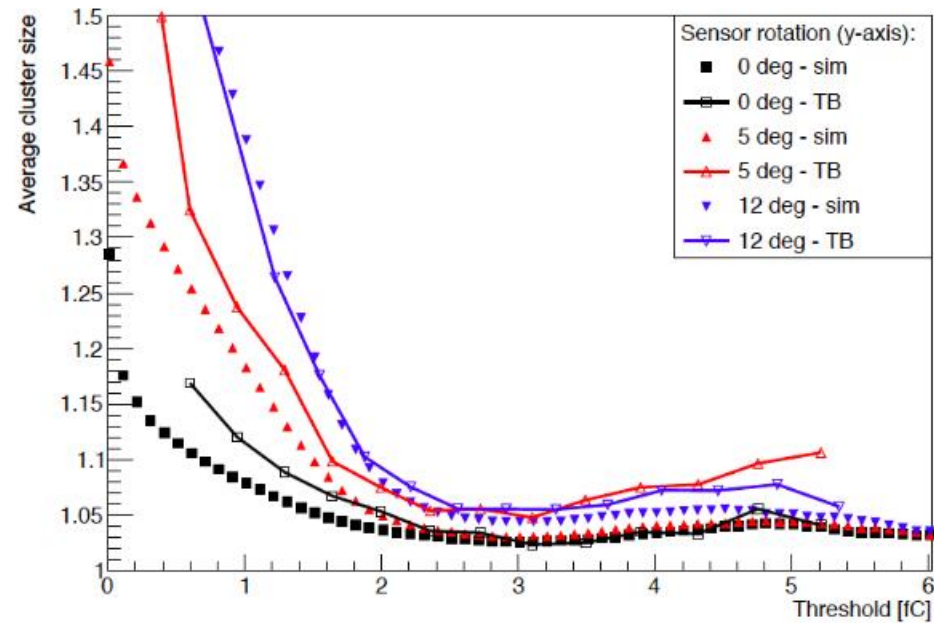
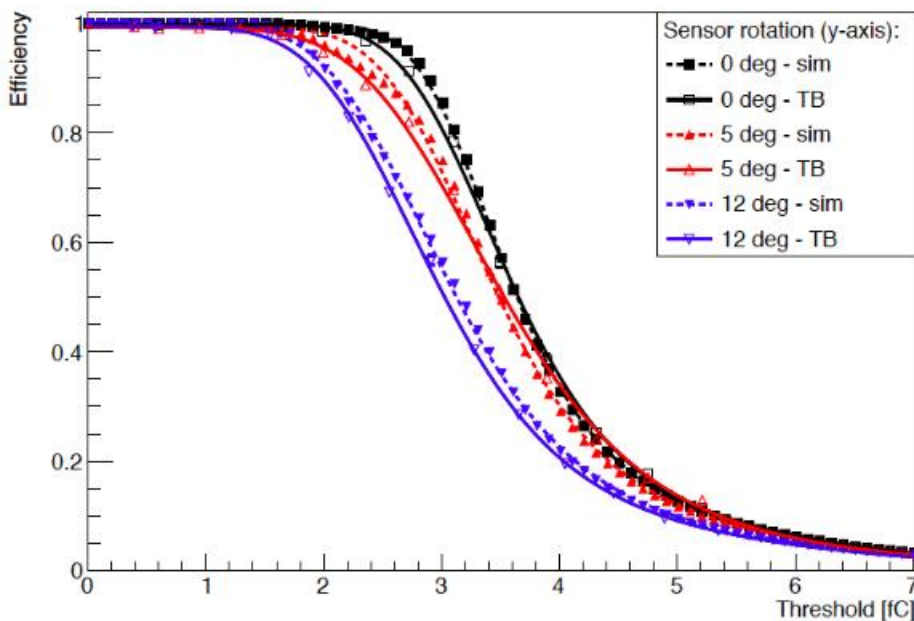
2020-07-14



LS module - Test beam vs. simulation



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

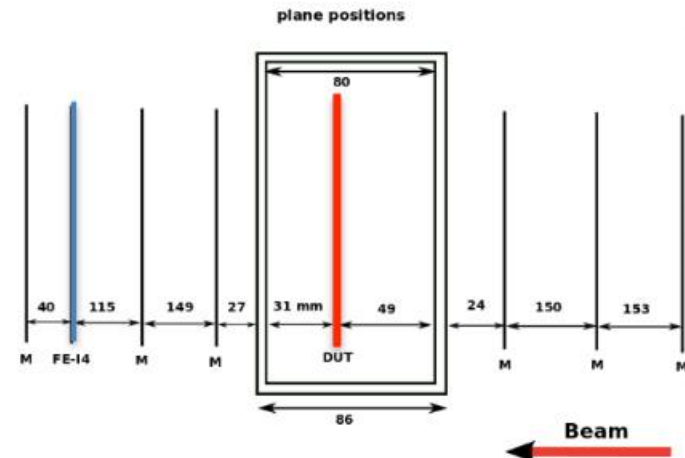


- **Work in progress**
 - Electric field maps and simulation being refined
- Overall good agreement of efficiencies from test beam and simulation
 - For average cluster size, trend is correctly described

Modules and Beam Tests

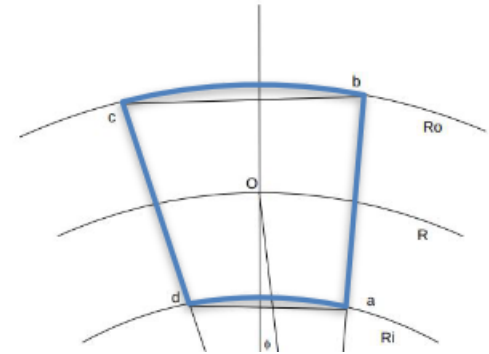
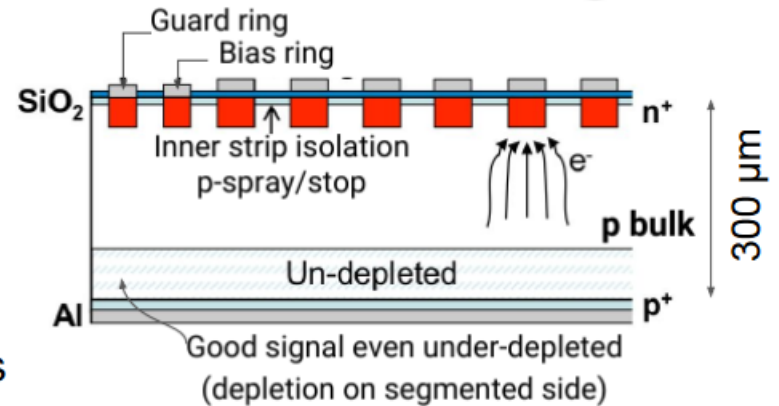


- In all cases EUDET-type beam telescopes comprised of six Mimosa planes and one FE-I4 or Alpipe timing plane
 - DURANTA at DESY
 - ACONITE at CERN
- Tracking resolution of
 - 5-10 μm at DESY
 - 3 - 5 μm at CERN
- Telescope and device under test (DUT) controlled and read-out using EUDAQ2



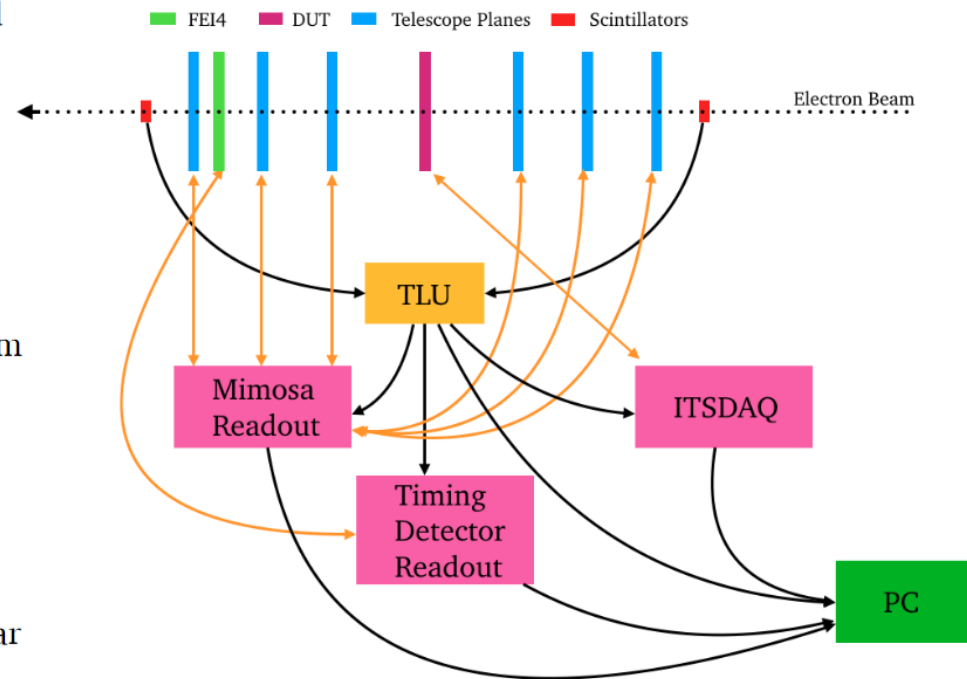
ITk Strip Detector

- 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

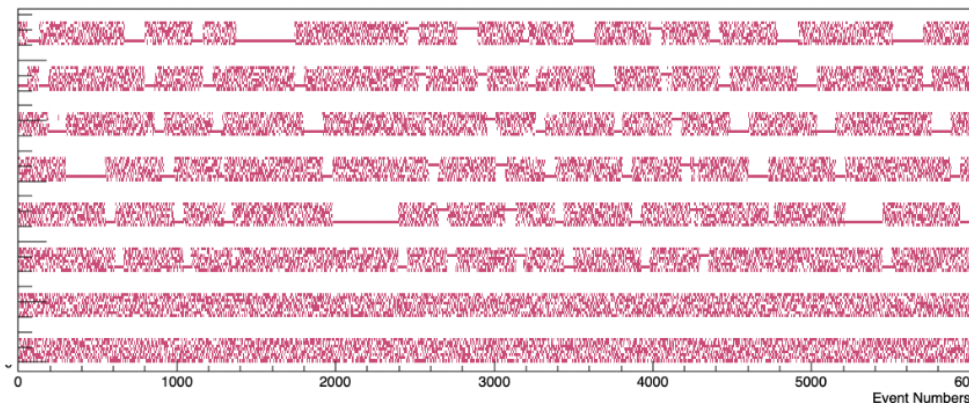
- During analysis of **April 2019 Testbeam** data we found that only **~30%** of events within a run were synchronised
- What does desynchronised data mean?
 - There is a mix up of the sub-event information
 - Events are assembled with sub-event information from each subsystems
 - Sometimes the wrong 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 led 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