高粒度量能器研究进展

张华桥（高能所）

高能所CMS高粒度量能器组

LHC升级威海会议，2018年6月28-29，威海

报告提纲

- CMS 高粒度量能器量能器总体进展情况
- 高能所高粒度量能器量能器任务进展
- 高能所高粒度量能器模块研究进展
- 总结

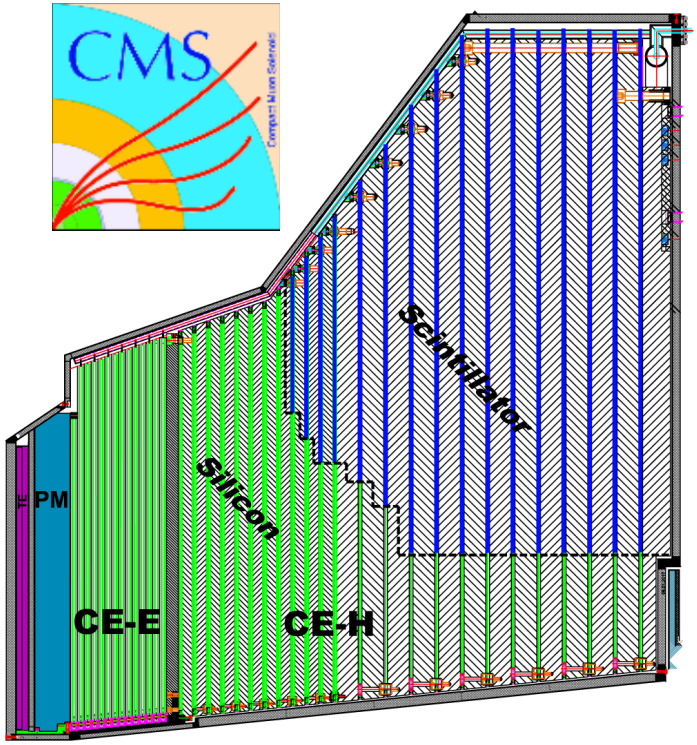
CMS 高粒度量能器项目

France/Prague/Japan/England

Years of R&D,
Application Not yet approved

Similar idea

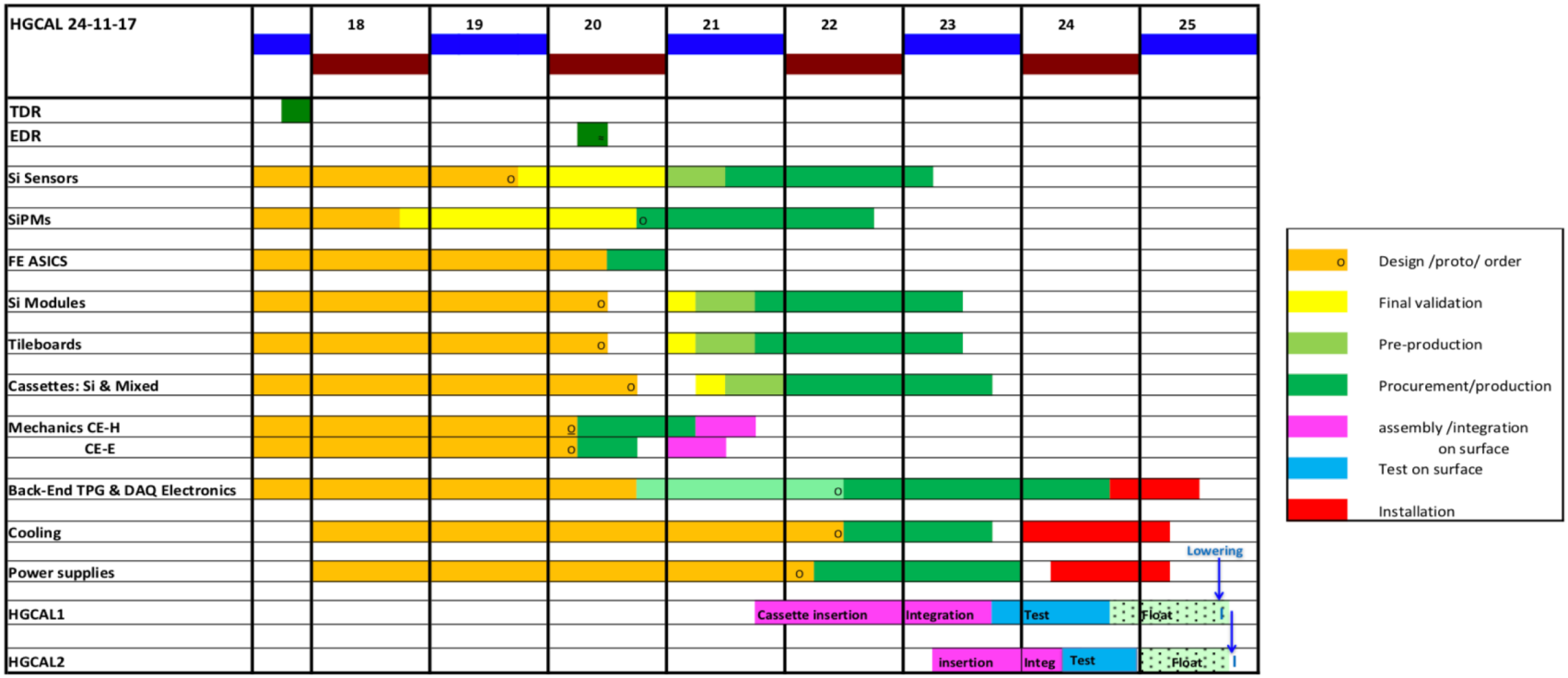
CMS HGC
Approved to be built 2015-2023



Other future HEP experiments

优点：可以达到1立方厘米一个探测读出
很好的能量，位置，时间分辨率：5D量能器

高粒度量能器项目时间表



Silicon modules (MO)

Module assembly pilot site and procedures setup 6″	CE.MO.2	28/11/2017
Module assembly pilot site and procedures setup 8″	CE.MO.3	24/12/2018
All module assembly sites and procedures qualified	CE.MO.4	08/06/2020
HGCROC-DV2 module qualified	CE.MO.5	25/06/2020
Module components orders placed	CE.MO.6	20/08/2020
Final module qualified	CE.MO.7	29/04/2021
Modules production 5% complete	CE.MO.8	14/10/2021
Modules production 50% complete	CE.MO.9	15/09/2022
Module production 100% complete	CE.MO.10	25/05/2023

项目整体进展顺利，通过了TDR

中国高粒度量能器项目进展

CMS-TDR-019
已经公开发表

- 明确了高能所在CMS合作组中HGC项目任务

China-IHEP_Beijing in CMS-HGCAL Phase 2 Upgrades Project

Dear Huaqiao,

CMS has undertaken to upgrade its endcap calorimetry for Phase 2 of the LHC. The Project comprises around 50 Institutes from over 15 countries. The HGCAL project shall be submitting a Technical Design Report (TDR) in November 2017 to the LHCC, the scientific peer review committee of CERN.

The HGCAL Project would like to see the following contributions from the China-IHEP_Beijing Group (with an initial CORE contribution of [redacted] MCHF):

- Pro-rata (Si+Scint cost/total cost) Contribution to Active Elements
- Contribute to sensor R&D, qualification and testing
- Contribute to fe chips testing
- Contribute to testing of on-detector electronics boards (PCBs)
- Host a silicon module assembly centre
- Contribute to EC_ECAL and EC_Hadronic assembly and test
- Contribute to 2nd cassette assembly centre at CERN (collective responsibility)
- Contribute to the installation and cabling/services in UXC
- Contribute to simulation and performance studies
- Contribute to test beam activities

Please check that the list conforms to our mutual understanding.

Yours sincerely,

CMS HGC负责人签署的高能所HGC任务书

Table 6.1: Cost and Responsibilities in the HGCAL Project.

	Item	Cost kChF	Funds kChF	Participating institutes
1.1	**Mechanical systems**			CERN, France (POLYTECNIQUE), RDMS-RF (PROTVINO, MOSCOW-INR), Turkey
1.1.1	Electromagnetic calorimeter	182		
1.1.2	Hadronic calorimeter	2814		
1.1.3	Support structure	482		
1.1.4	Cooling and thermal screen	6420		
1.1.5	Dry gas system	60		
1.1.6	Mechanical assembly	580		
	Total	**11738**		
1.2	**Cassettes**			France (POLYTECNIQUE), Germany (DESY), RDMS-RF (PROTVINO, MOSCOW-INR, MOSCOW-LEBEDEV, MEPHI), USA (ALABAMA, BROWN, FAIRFIELD, FERMILAB, FLORIDA-TECH, FLORIDA-STATE, IOWA, MIT, NORTHWESTERN, NOTRE DAME) *Assembly centres:* CERN and FERMILAB
1.2.1	Electromagnetic calorimeter	1110		
1.2.2	Hadronic calorimeter (Si only)	417		
1.2.3	Hadronic calorimeter (Mixed)	1078		
1.2.4	Cassette assembly centres	298		
	Total	**2914**		
1.3, 1.4	**Silicon sensors and Modules**	27345		**All funding agencies will participate in the purchase of silicon sensors** *Module assembly centres:* China (BEIJING-IHEP), India (MUMBAI-BARC), Taiwan (CHUNGLI-NCU, TAIPEI-NTU) USA (CARNEGIE-MELLON, TEXAS-TECH, UCSB)
1.5	**Scintillator modules**	2925		Germany (DESY), RDMS-RF (PROTVINO, MOSCOW-INR, MOSCOW-LEBEDEV, MEPHI), RDMS-DMS (DUBNA, KHARKOV-KIPT, KHARKOV-ISMA, MINSK-INP), USA (FAIRFIELD, FERMILAB, IOWA, MARYLAND, NORTHERN ILLINOIS, NOTRE DAME, ROCHESTER) *Scintillator module assembly centres:* RDMS-RF (PROTVINO), RDMS-DMS (DUBNA, others?), xxx, etc

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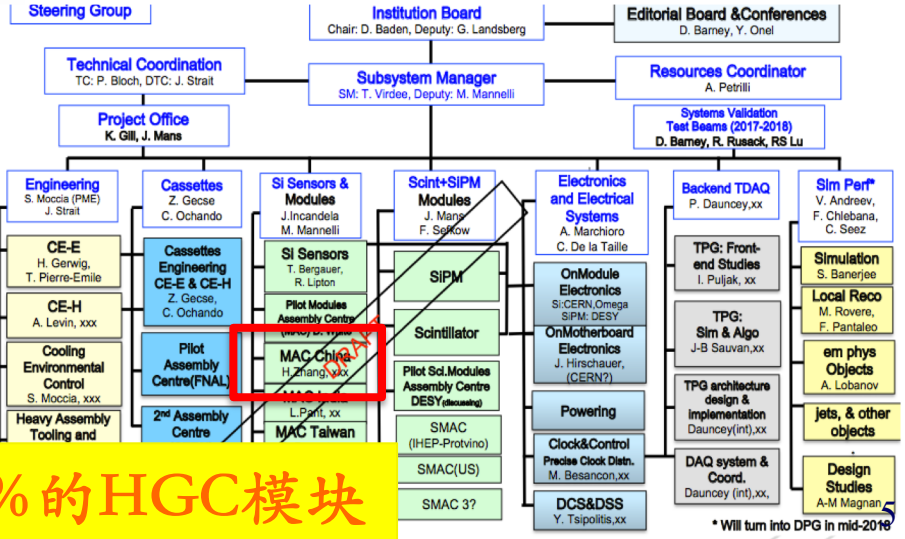
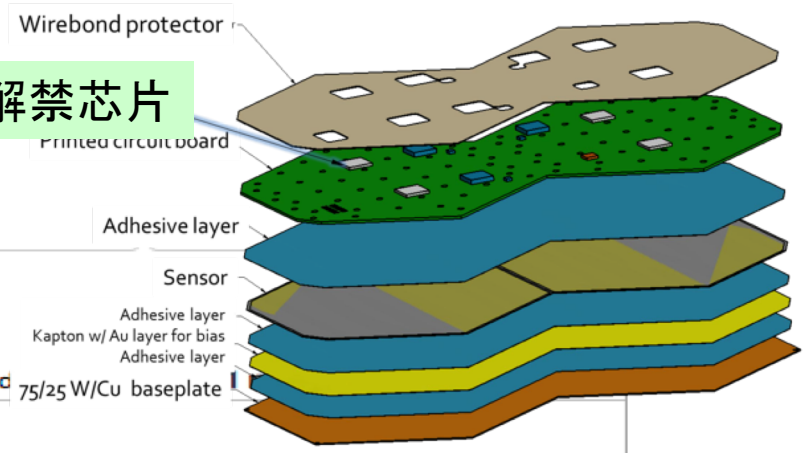
TDR中的组织结构图



中国可能将生产20%的HGC模块

中国高粒度量能器项目进展

- HGC芯片禁运取得重要进展
  - HGC芯片到高能所没有问题



From Tejinder Virdee <tejinder.virdee@cern.ch>
Subject **Export Licence**
To huaqiao Zhang, Hesheng Chen <chenhs@ihep.ac.cn>
Cc Tejinder Virdee <tejinder.virdee@cern.ch>, Drew Baden <drew@umd.ed

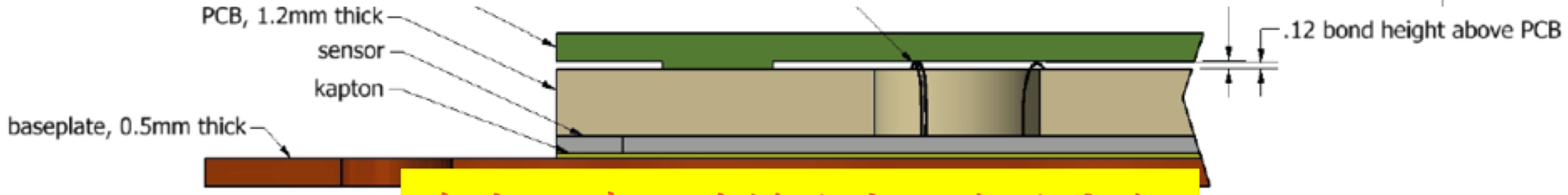
Dear Hesheng and Huaqiao,

Tiziano has now obtained very encouraging information from CERN, who are in contact with the relevant Swiss authorities, concerning the Export licence. This is summarised in the following statement:

"From the experience gained so far for temporary export licence of dual use electronics chips (for reference they are the class of devices identified by the code3A001.a.1.a of the Annex 2 OCB (Ordonnance sur le Control des Biens CH) received at CERN no problem has been encountered when dealing with Chinese institutes (including IHEP Beijing).

We remind you that regarding electronics developed at TSMC, Taiwan, the temporary export licence will have to be requested, for each chip and for each shipment, from SECO (the swiss State Secretariat for Economic Affairs) through CERN"

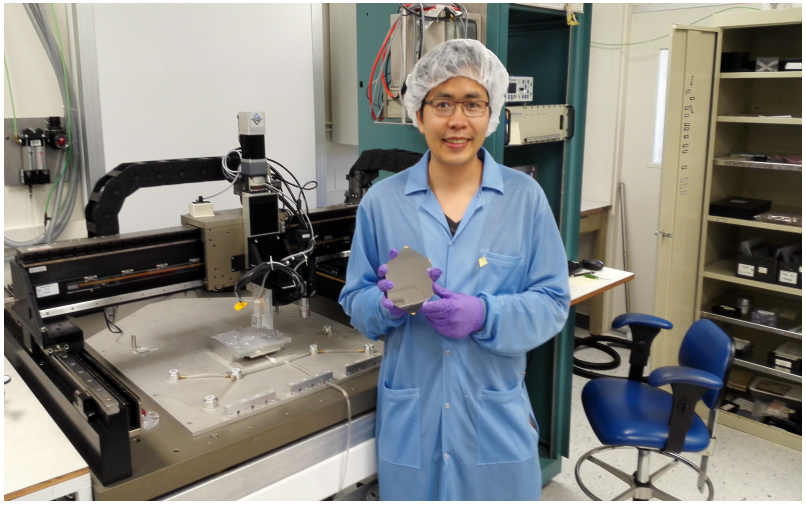
Best Regards,
Jim



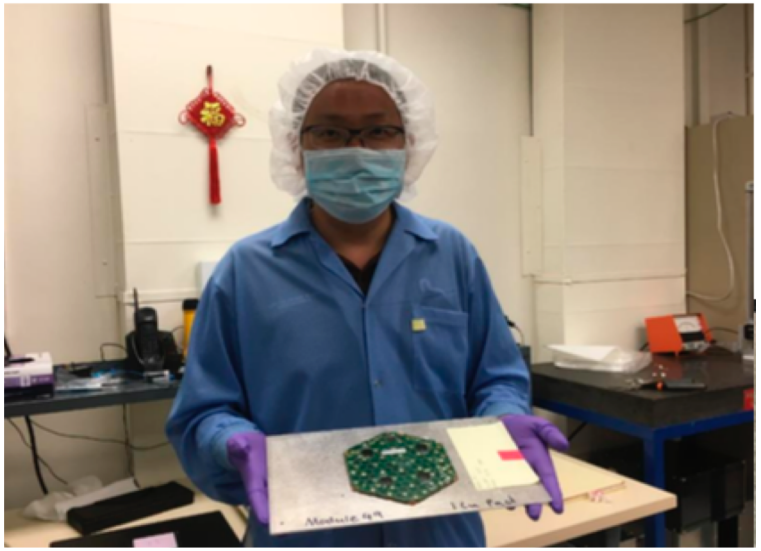
在中国建立硅模块中心条件齐备

高能所高粒度量能器量能器任务进展

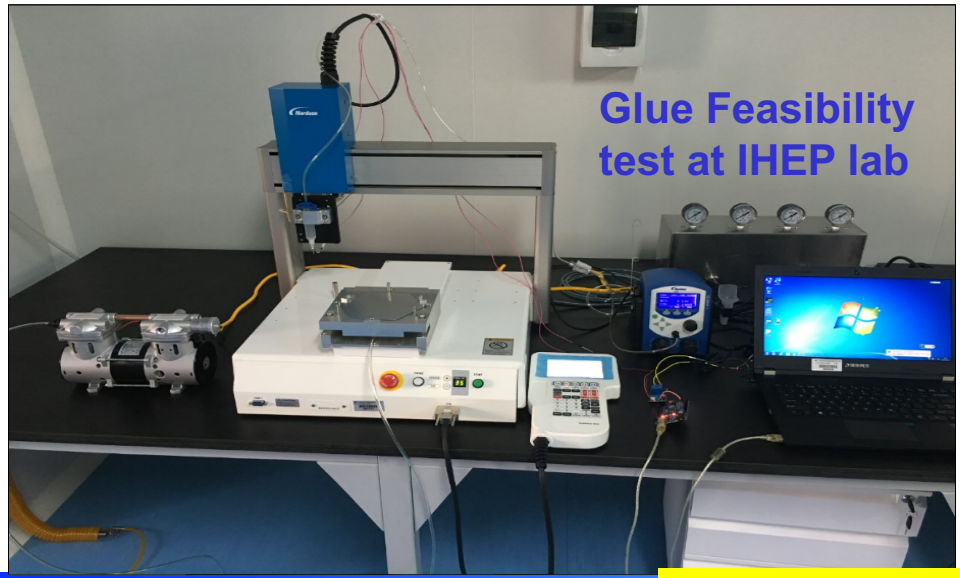
高能所参与HGCal硅模块组装



Huaqiao ZHANG participate The first beam test HGC module production at UCSB in Mar. 2016



07-08/2017, Feng WANG join module production at UCSB

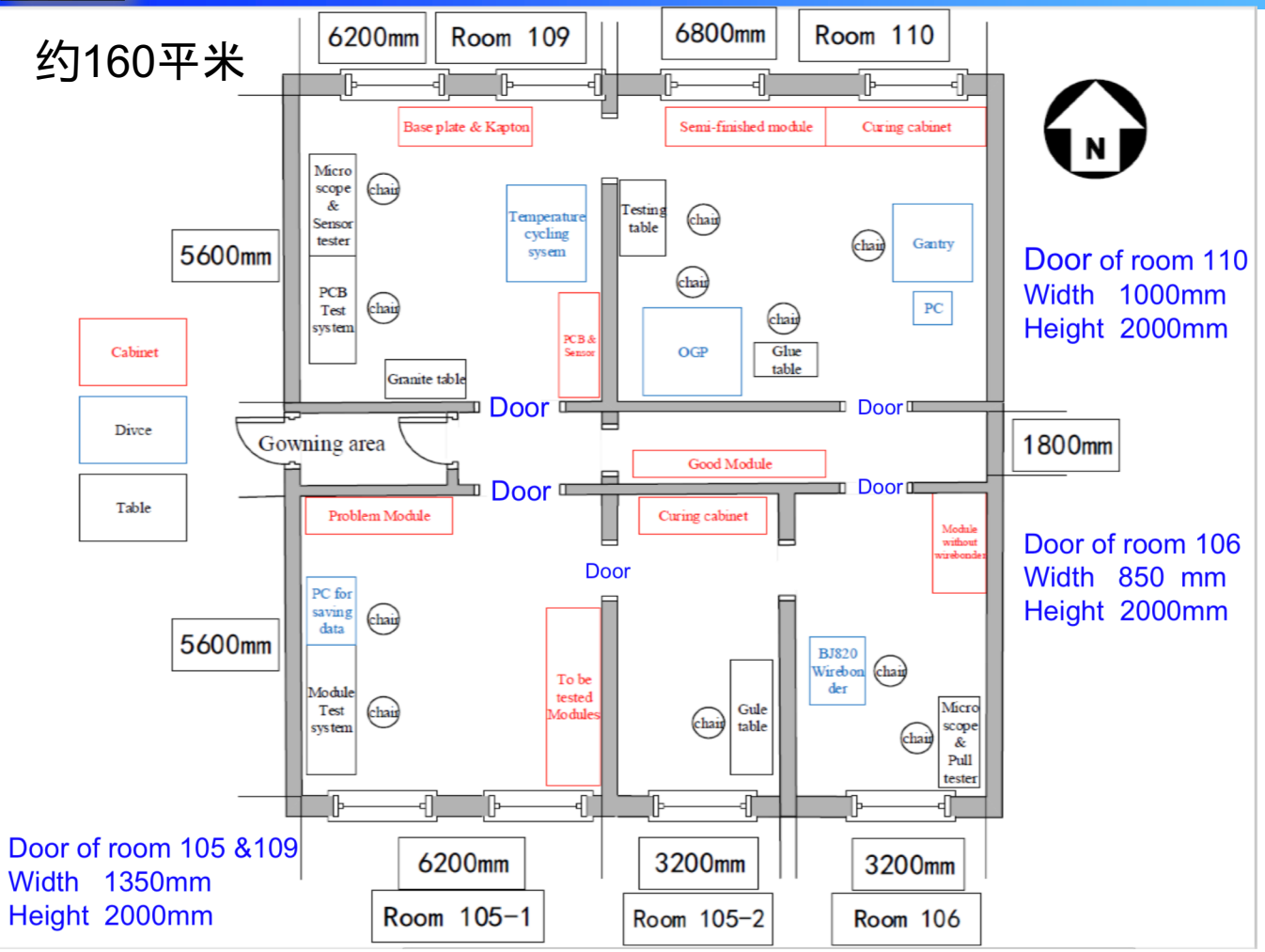


Regular visiting to UCSB
- 2016/03: H. Zhang
- 2017/07: F. Wang
- 2018/02: F. Wang
- 2018/04: H. Zhang

共计 4.5个人月

高能所HGCal实验室建设

约160平米



邦定机招标采购

- 四号厅四间办公室改造
- 邦定机采购开标（2017/12/26）

Planned HGCal clean room
Could start construct ~Sep

高能所实验室建设充分继承国际上先行HGC实验室建设经验

中国高粒度量能器实验束测试研究

- HGC样机的束流实验
  - 从参与到可能的主导

即将运到中国的HGC宇宙线/束流测试系统

HGC束测时间	地点	IHEP贡献
2016/03/21-04/12	FNAL	
2016/04/18-27	CERN	
2016/08/17-24	CERN	
2016/08/31-09/07	CERN	
2016/11/09-14	CERN	
2017/5/8-15	CERN	
2017/7/12-19	CERN	
2017/09/29-10/02	CERN	
2017/10/18-23	CERN	
2018/03/16-28	DESY	
2018/06/08-16	CERN	
2018-	IHEP？	

原创的Proposal获得HGC决策层支持

Proposal for measuring the energy response linearity of HGCal silicon sensor at high MIP signal using IHEP-Beijing test beam facility

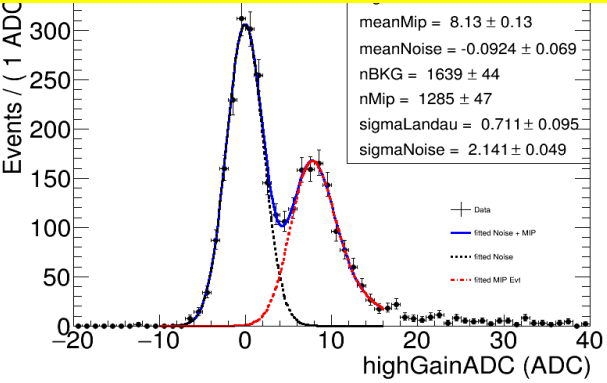
CMS HGCal is designed to measure EM and Hadronic energy deposited at the end cap part of CMS detector. A typical electron with 100 GeV of pT at Eta = 2.5, will have about 613 GeV of energy deposited as a shower in the calorimeter. HGCal uses silicon sensor to sampling this shower. Is the silicon sensor has good energy response linearity up to the HGC FE readout range of 3000 MIPs? Is the linearity is uniform across the module? Whether radiation bring extra non-linearity of

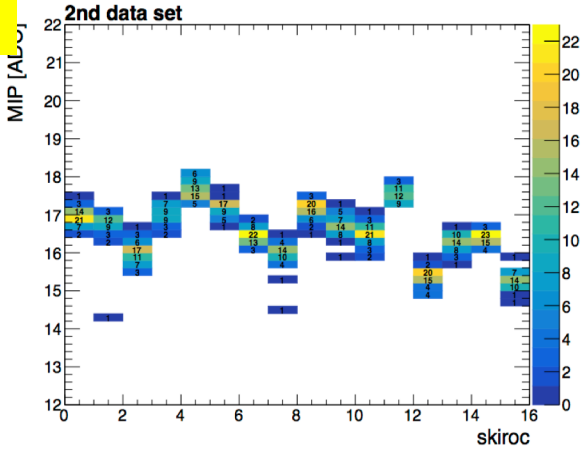
多人次参与HGC束流实验，2018年部分TB将在IHEP进行

中国高粒度量能器项目进展

- HGC束流数据分析成果： DN-17-011, 提交到JINST
- HGC TDR: CMS-TDR-17-007

首个MIP信号@费米: Calor2016

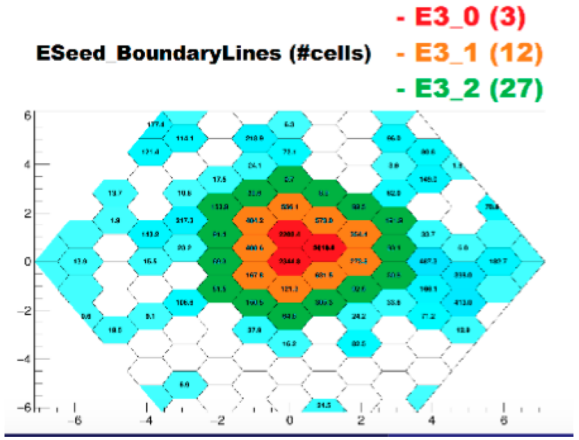




Available on the CMS information server

CMS DN-17-011

IAS/TIPP/ALC2018 国际大会做关于HGC的报告



The Compact Muon Solenoid Experiment

CMS Draft Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

2017/06/18
Head Id: 411064
Archive Id: 411057:411080
Archive Date: 2017/06/18
Archive Tag: trunk

准备中的单独实验束文章

First beam tests of prototype silicon modules for the CMS High Granularity

CERN European Organization for Nuclear Research
Organisation européenne pour la recherche nucléaire

CERN-LHCC-2017-023
CMS-TDR-17-007
27 Nov 2017

CMS

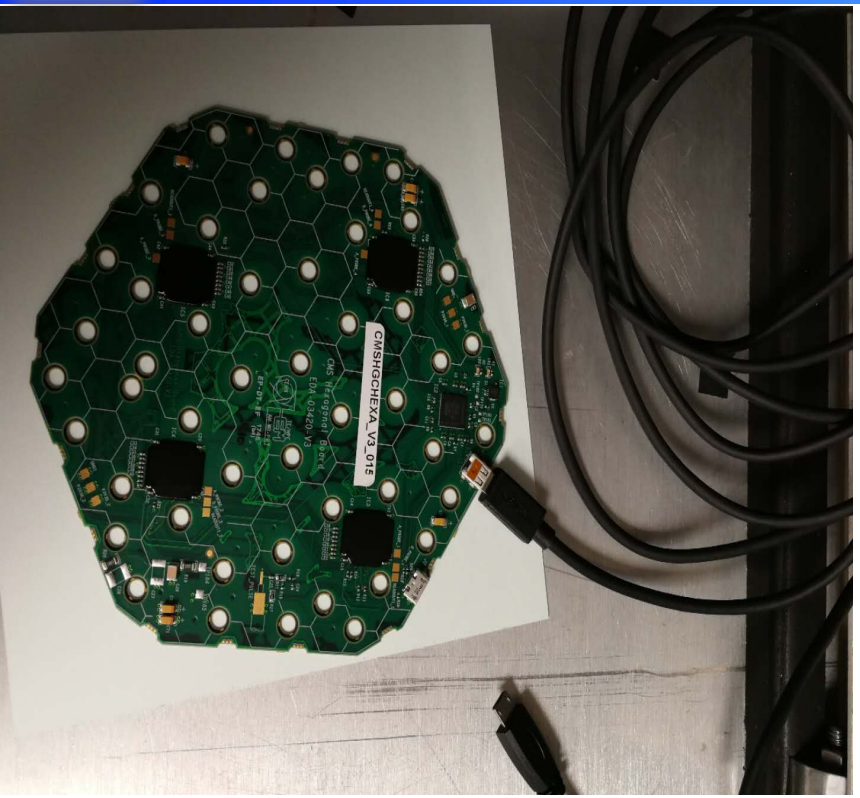
HGC TDR

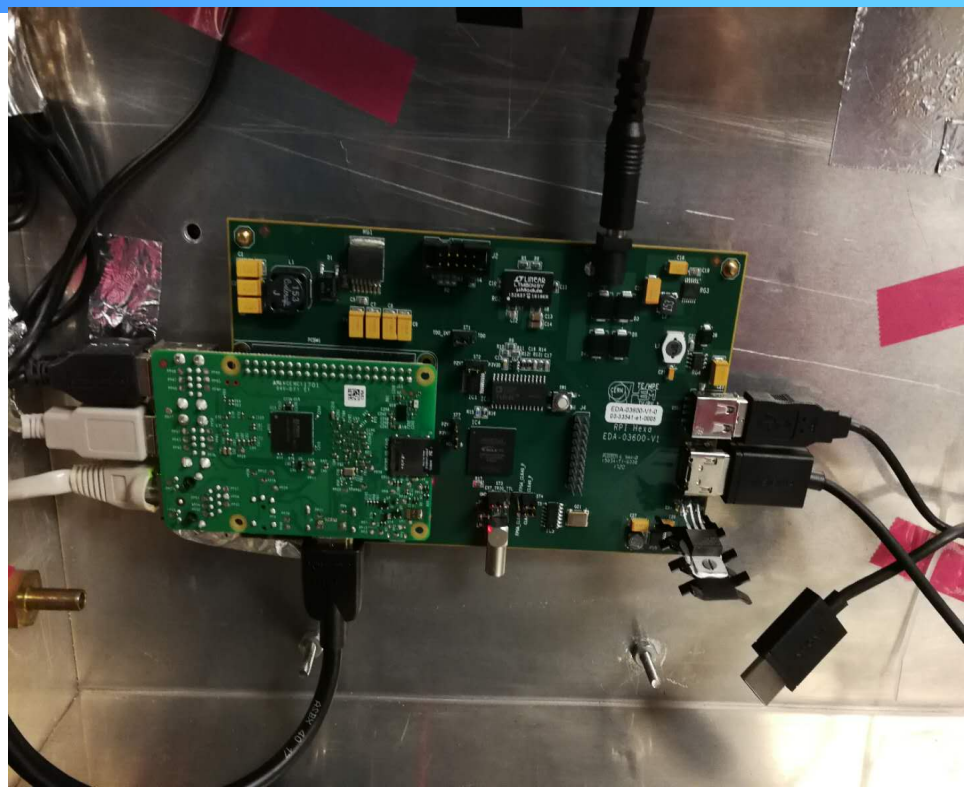
对实验束MIP信号进行了长期系统研究

高能所高粒度量能器模块研究进展

- PCB测试
- 高压保护环漏电流研究
- 宇宙线和束流测试研究

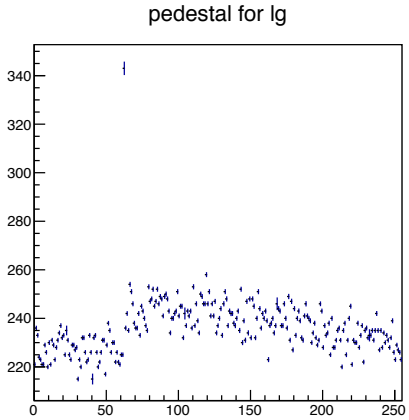
PCB测试

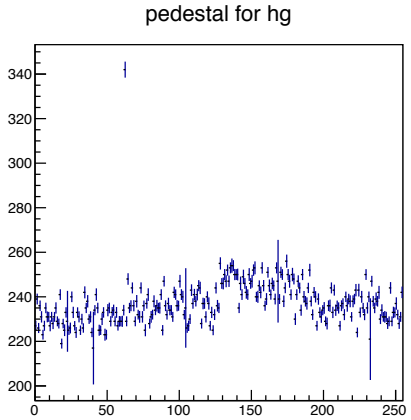


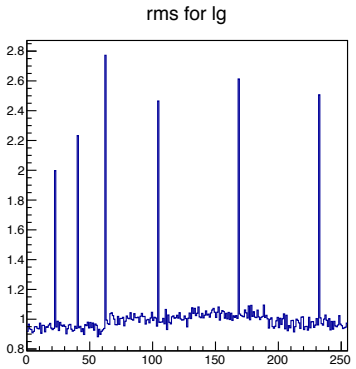


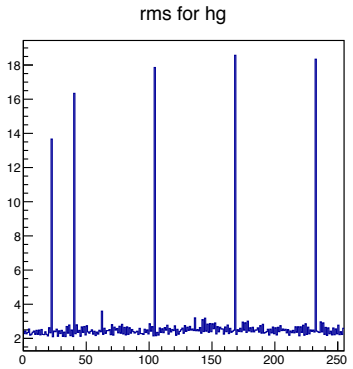
- 今年4月在UCSB进行测试
- 30 V3 boards（Eltos:6，CERN:8，Plotech: 16）
  - 2018年束流测试的模块
  - 探索质量控制的流程

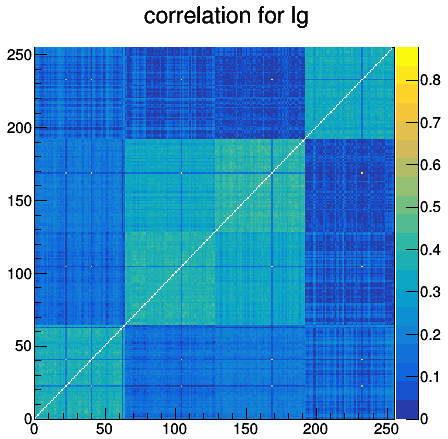
Pedestal, Noisy and correlation between channels

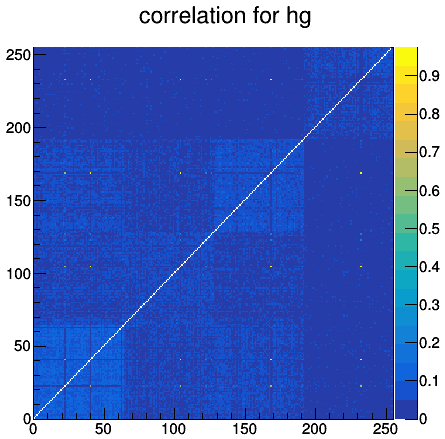












电子学噪声调查

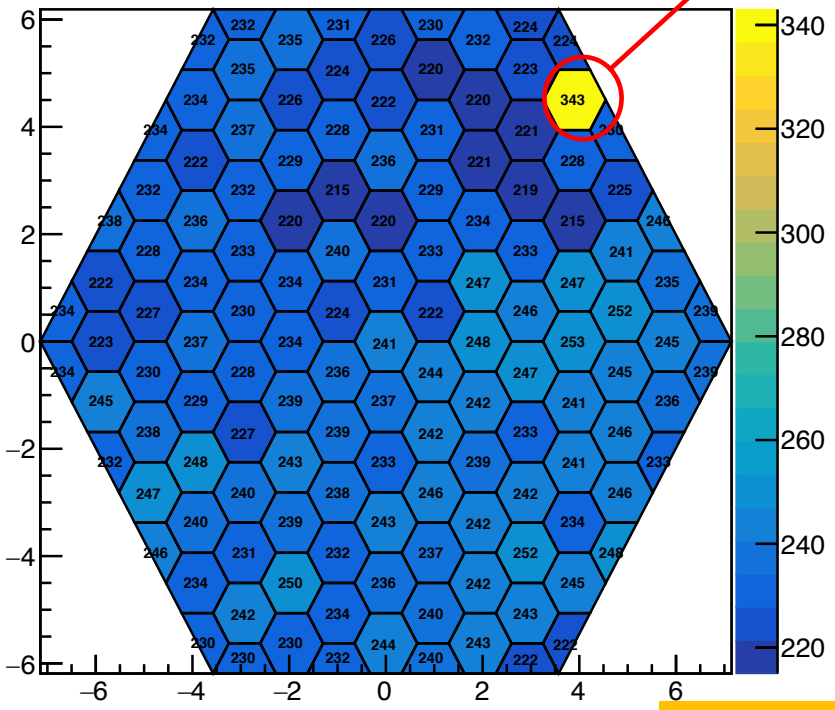
所有30块PCB的测试结果放在我的googledoc中：
https://drive.google.com/drive/folders/1hBRPW5UNxGKM-li7HuoyfVFMLA82pUkD

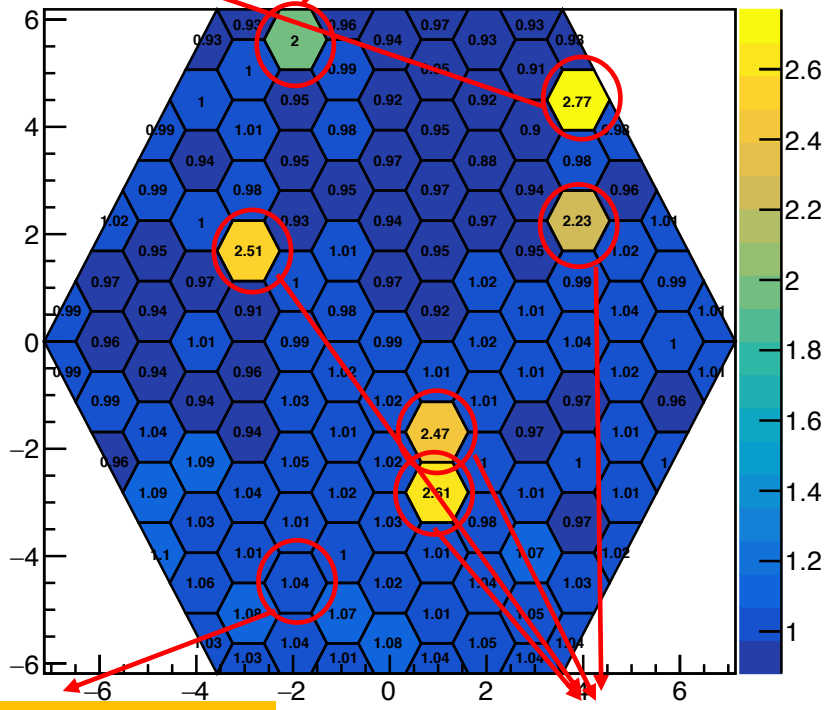
Chip 0, channel 62, High Ped only seen in this board

Chip 0, channel 22

Mean (ADC) for lg sca 1

ed RMS (ADC) for lg sca 1

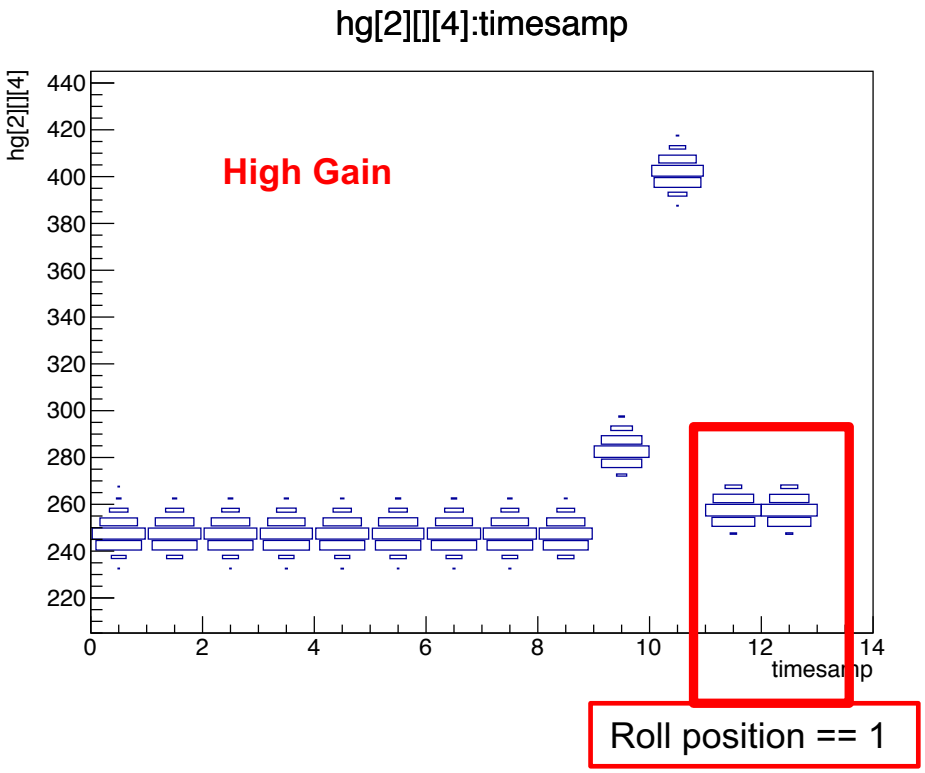


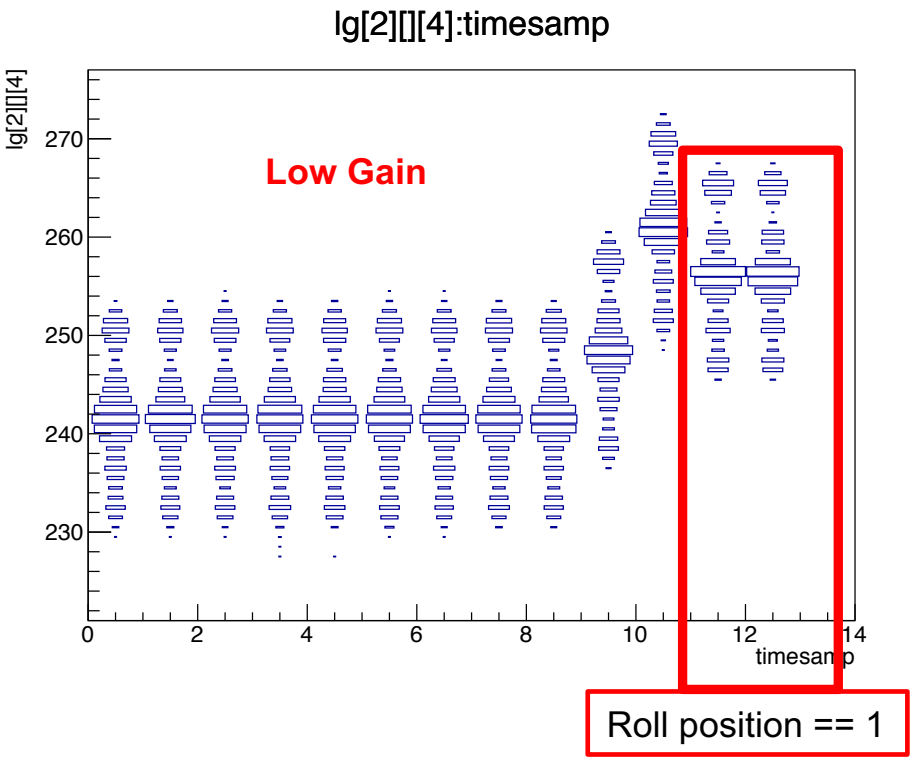


Chip2, channel 4, strange behavier

Chan 40 for chip 0,1,2,3

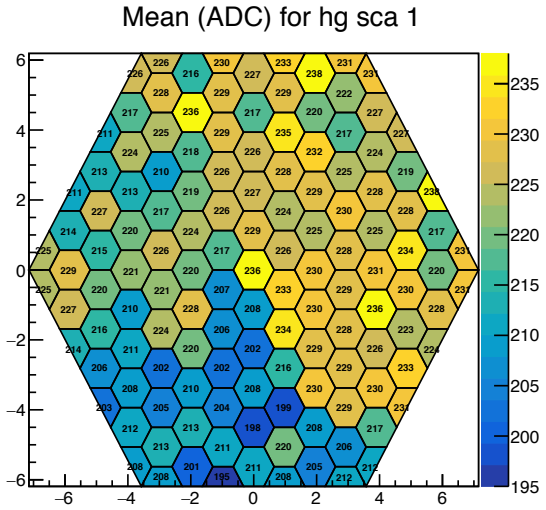
Example: Chip 2, channel 4:

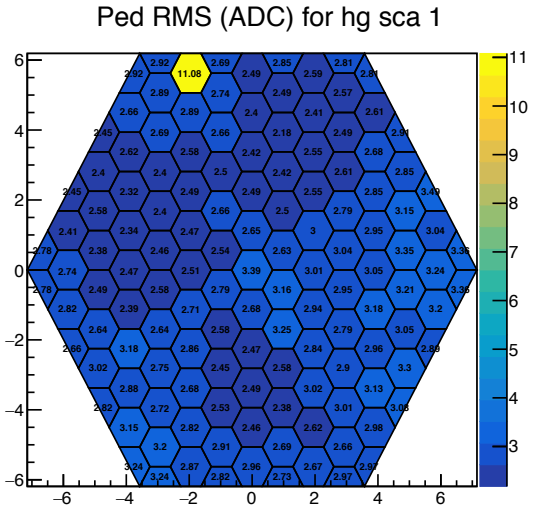


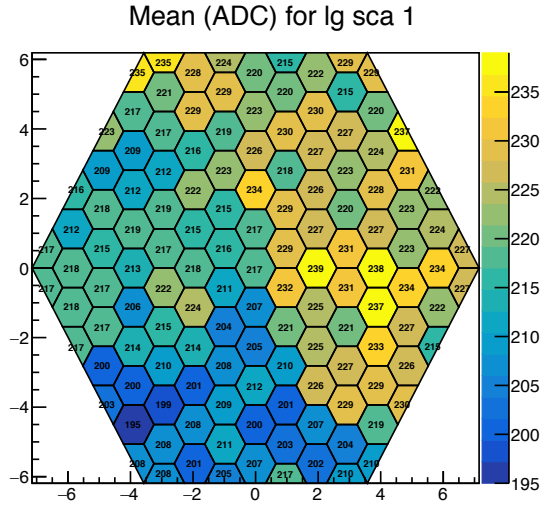


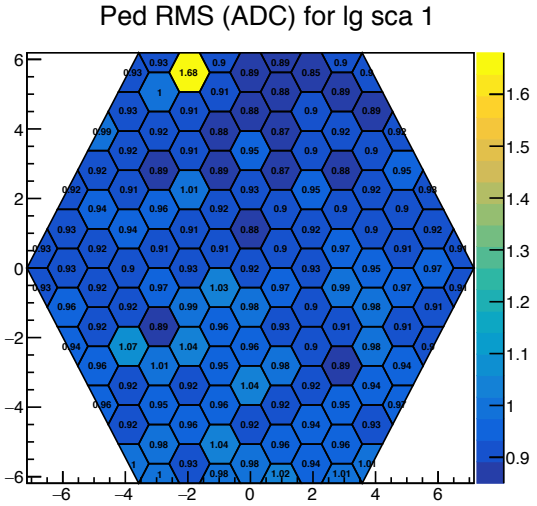
计划在把ASIC邦定到PCB前增加一道ASIC测试

研究结果





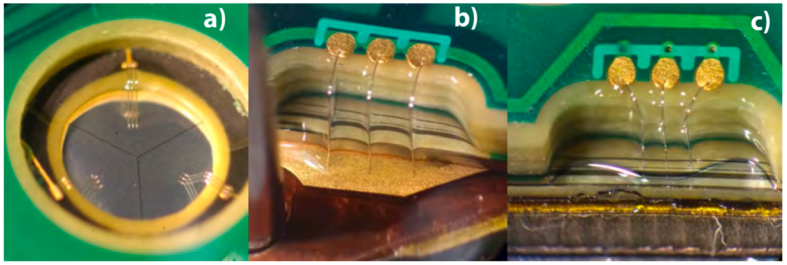


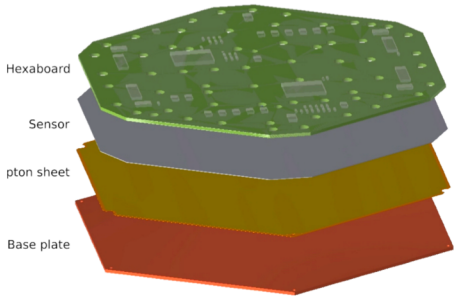


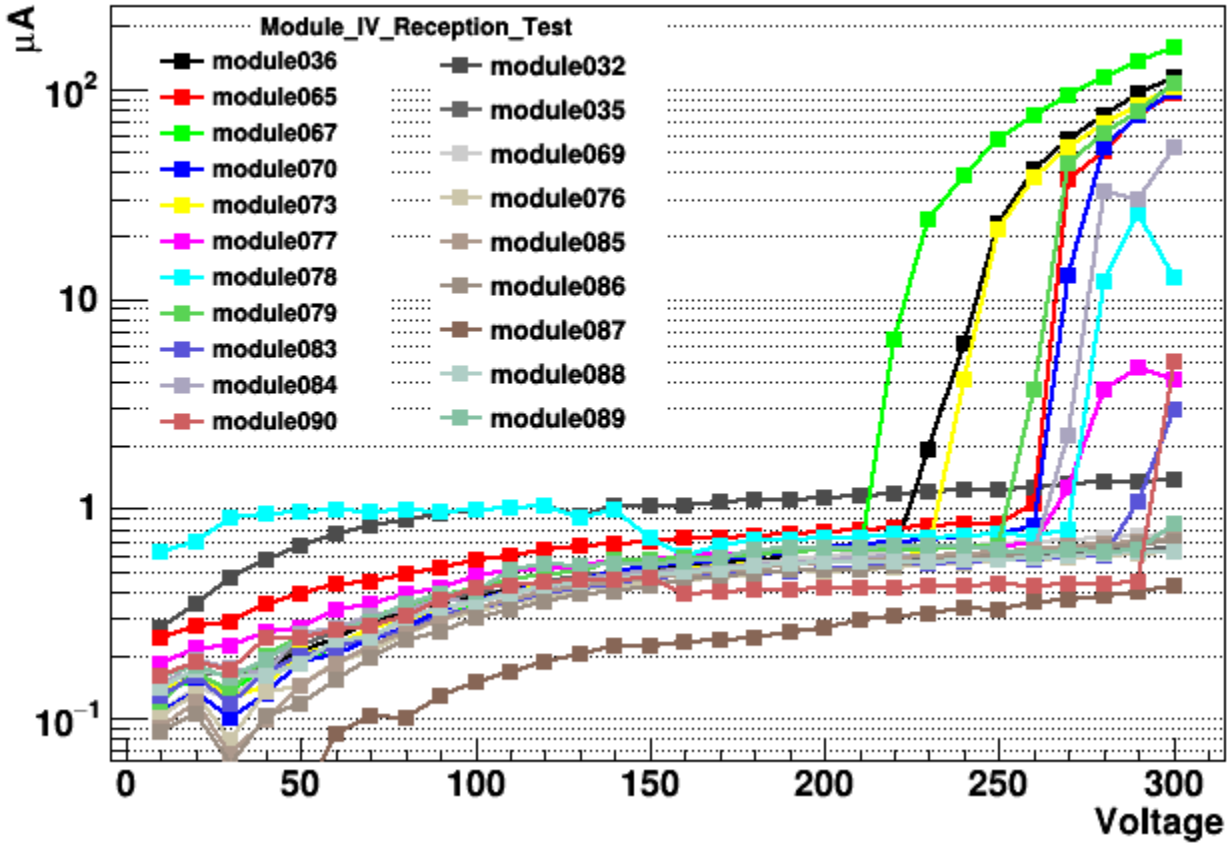
- Chan 40, chip 0, 1, 2, 3 was fund to be a configuration problem!
  - Charge injection is on ….. I Turn off it and test on one board

硅模块保护环高压漏电流研究

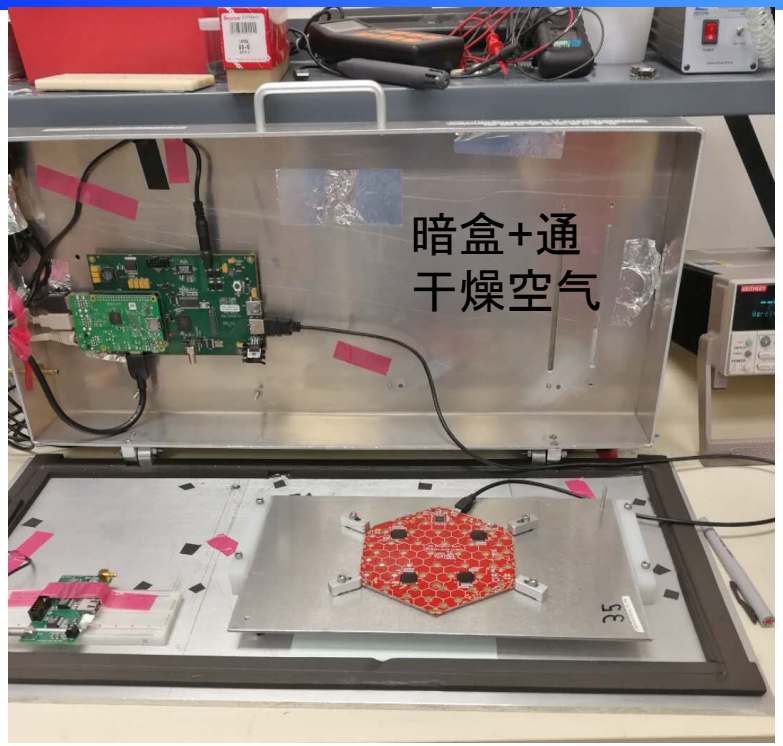
- 在模块组装之前，硅模块保护环电压可以加到1100伏，漏电流仍然很小
- 但是组装成硅模块后：

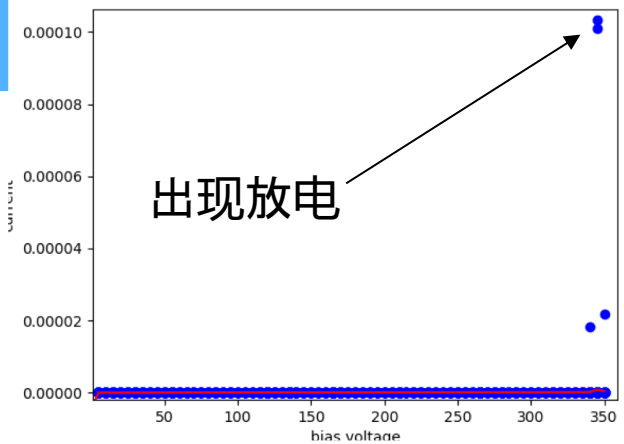


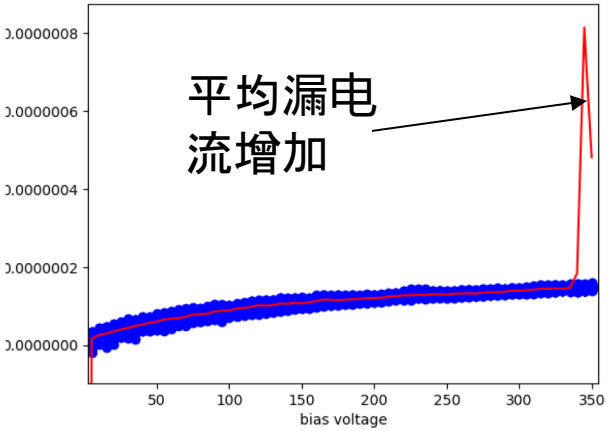


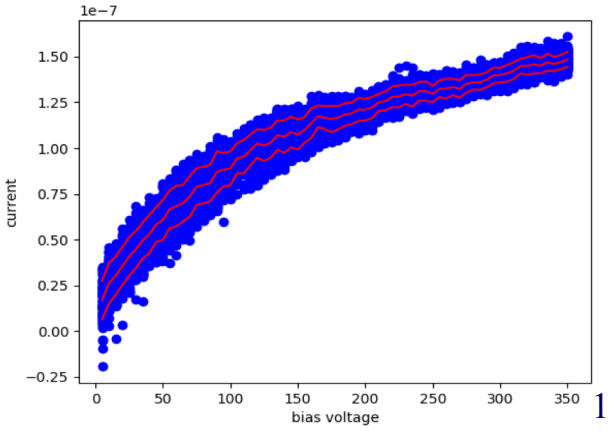


保护环漏电流的研究







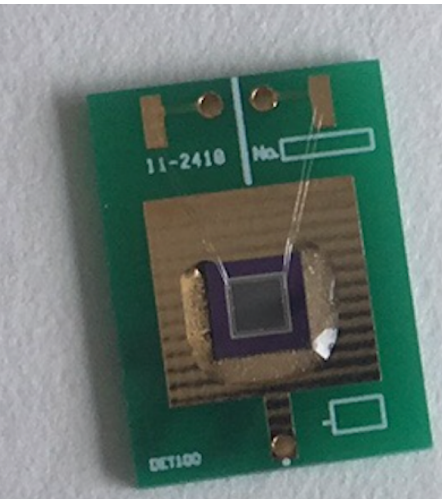


- 在UCSB进行了相关的测试
  - 测试组装各个步骤中的保护环漏电流
- 湿度控制在<1%，保持12小时左右
  - 保持48小时后放电电压增加到～600伏
- 与湿度相关

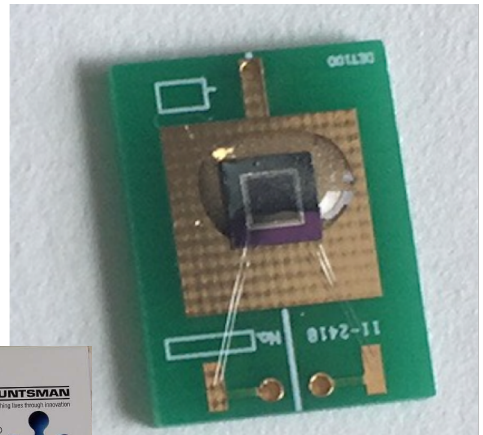
高能所对保护环漏电流的研究

孙亮，曹学雷，张万昌

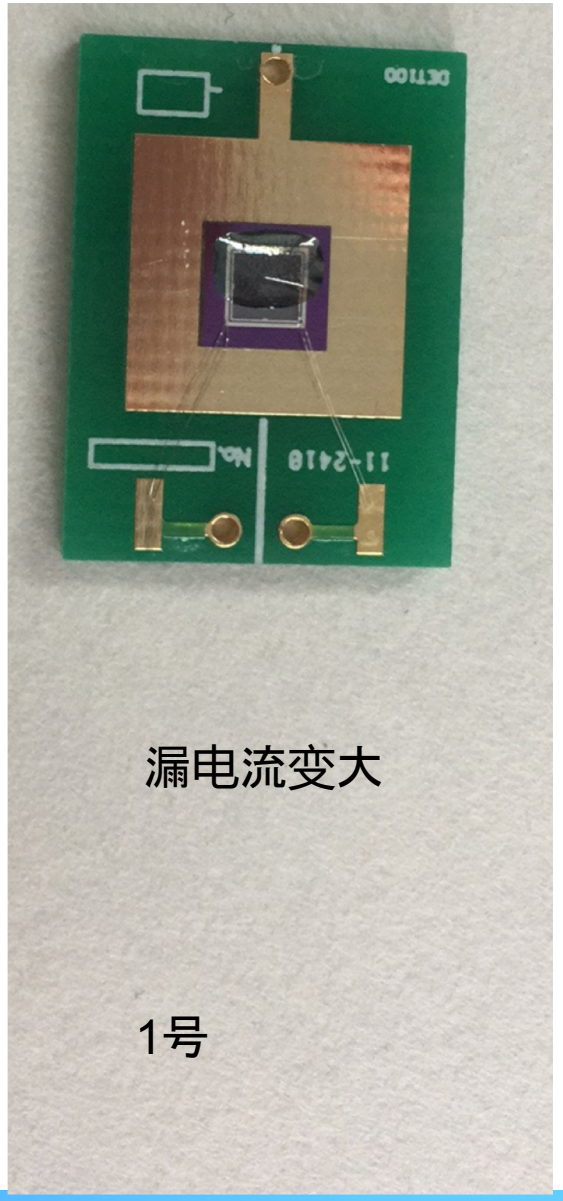
- 水汽 + 污染？ 温度20度，湿度40%



没有影响



漏电流变大



漏电流变大

涂胶到保护环上就会引起漏电流增加
➔ 增加隔离“保护环”的装置？

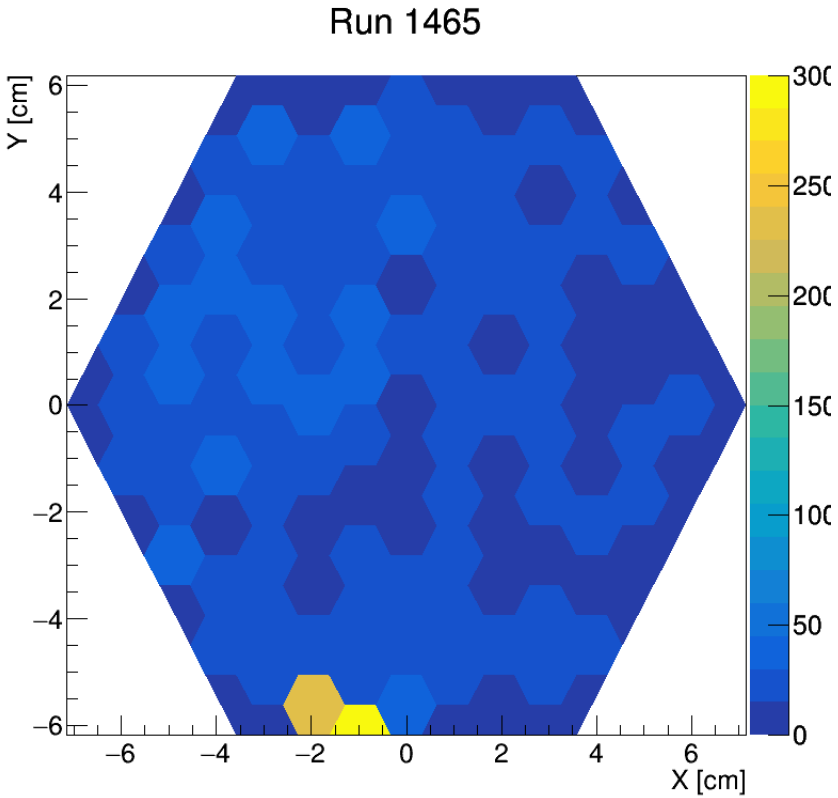
2#

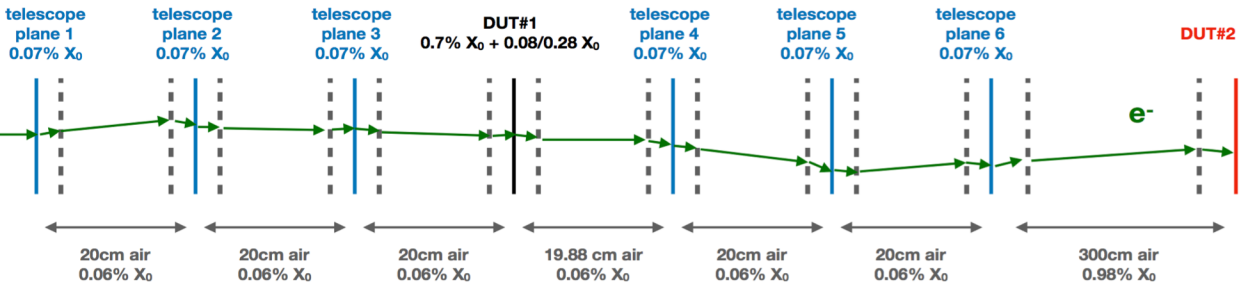
3#

1号

DESY 2018年3月实验束

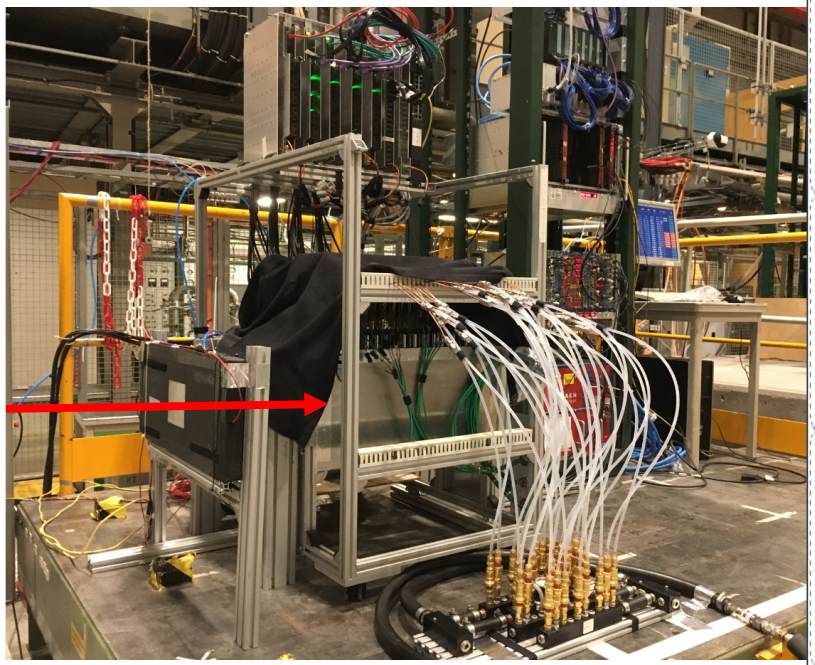
- 主要目标:硅Sensor 间隔对MIP探测效率的影响
- 次要目标:硅模块物质量的分布

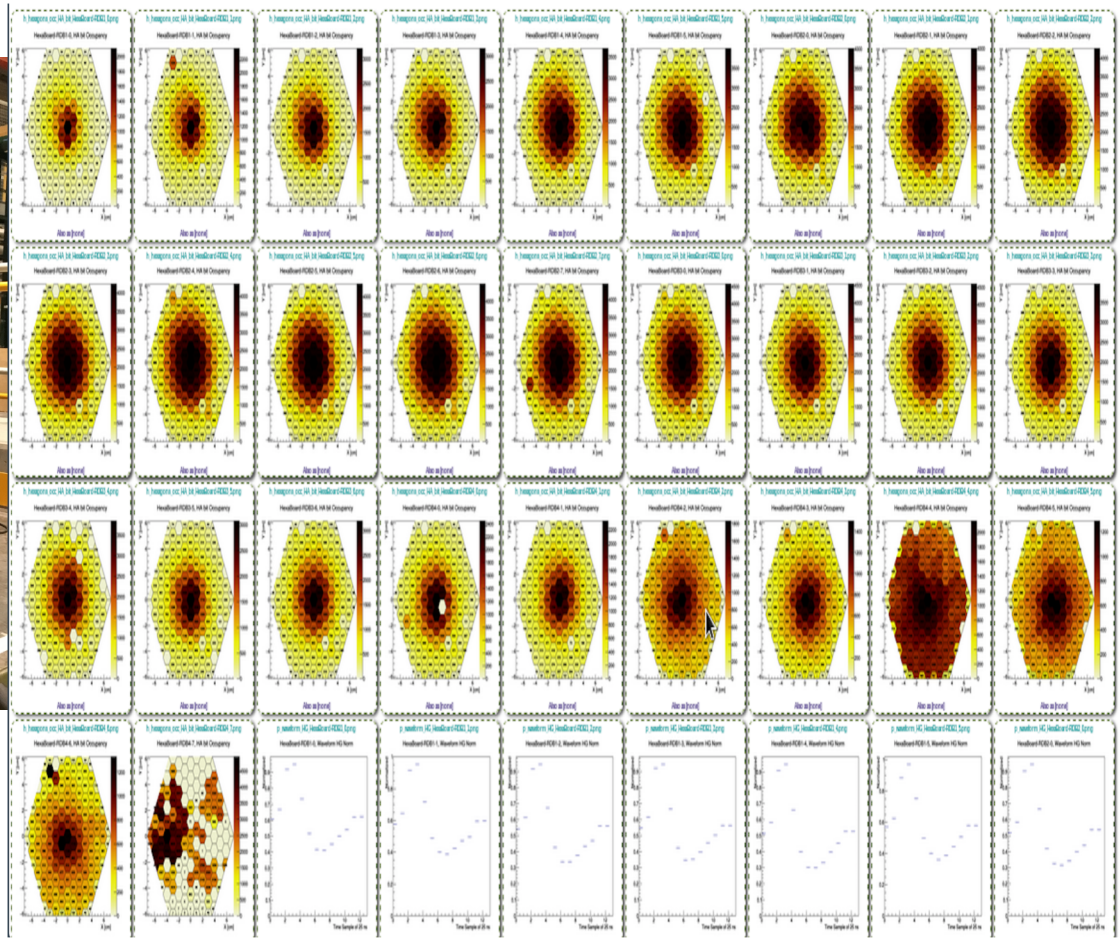




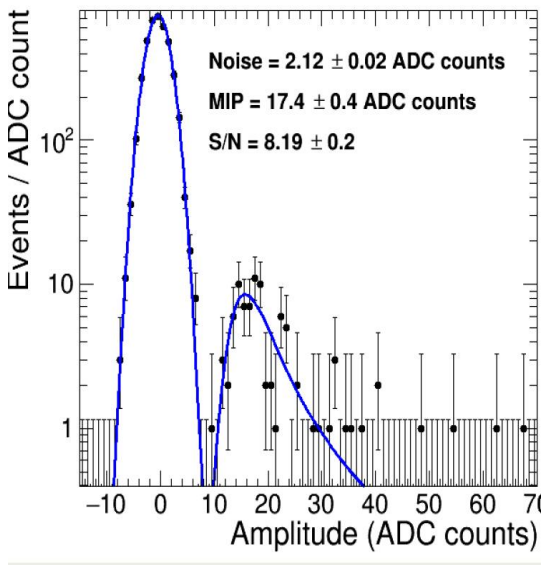
CERN 2018年6月 实验束

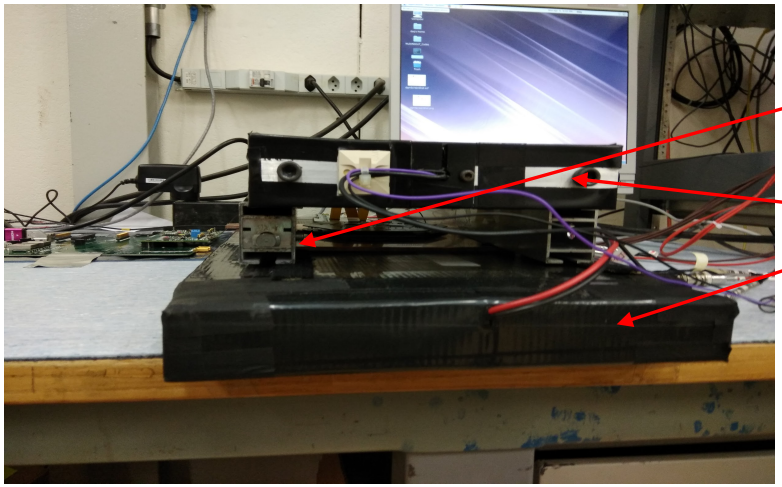
- 首次完整的28层电磁量能器系统
- 主要目标:电磁簇射的研究

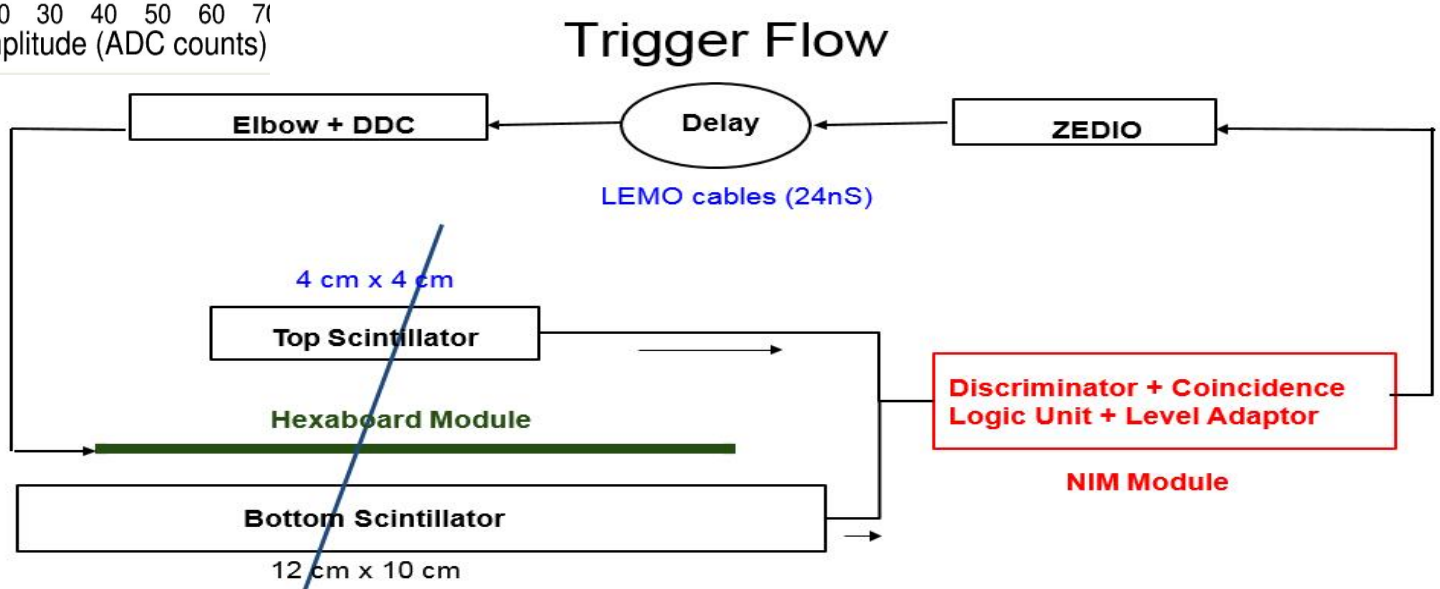




HGCal 宇宙线





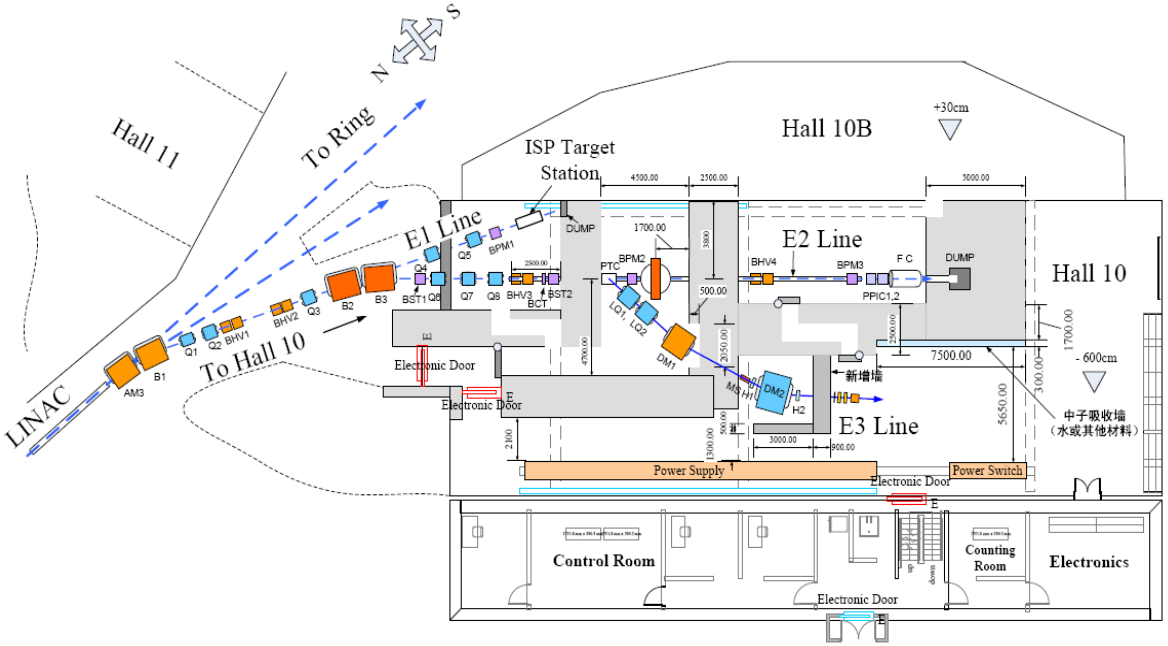


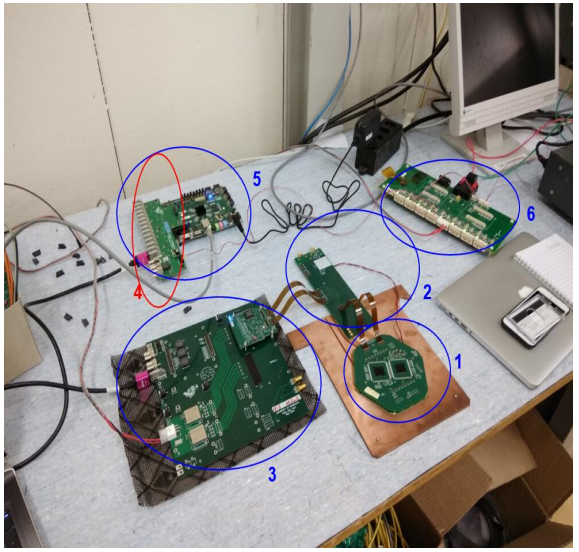
✓ *主要材料正在安排由CERN邮寄到高能所；*

✓ *～七月能在高能所搭建自己的系统*

Plan of beam test at IHEP

- Primary electron beam up to 2.5 GeV, 10^3–10^{10} electron/bunch
  - 12.5 – 50 Hz, beam length 10ps, beam size mm to ~5cm
- Secondary e/p/pi beam up to ~1.2 GeV
- HGCal test beam at IHEP (after 09/2018, full year beam time)
  - High MIP linearity tests
  - Backup when no beam at CERN (2019,2020)
  - Discussed with David Barney and keep talking



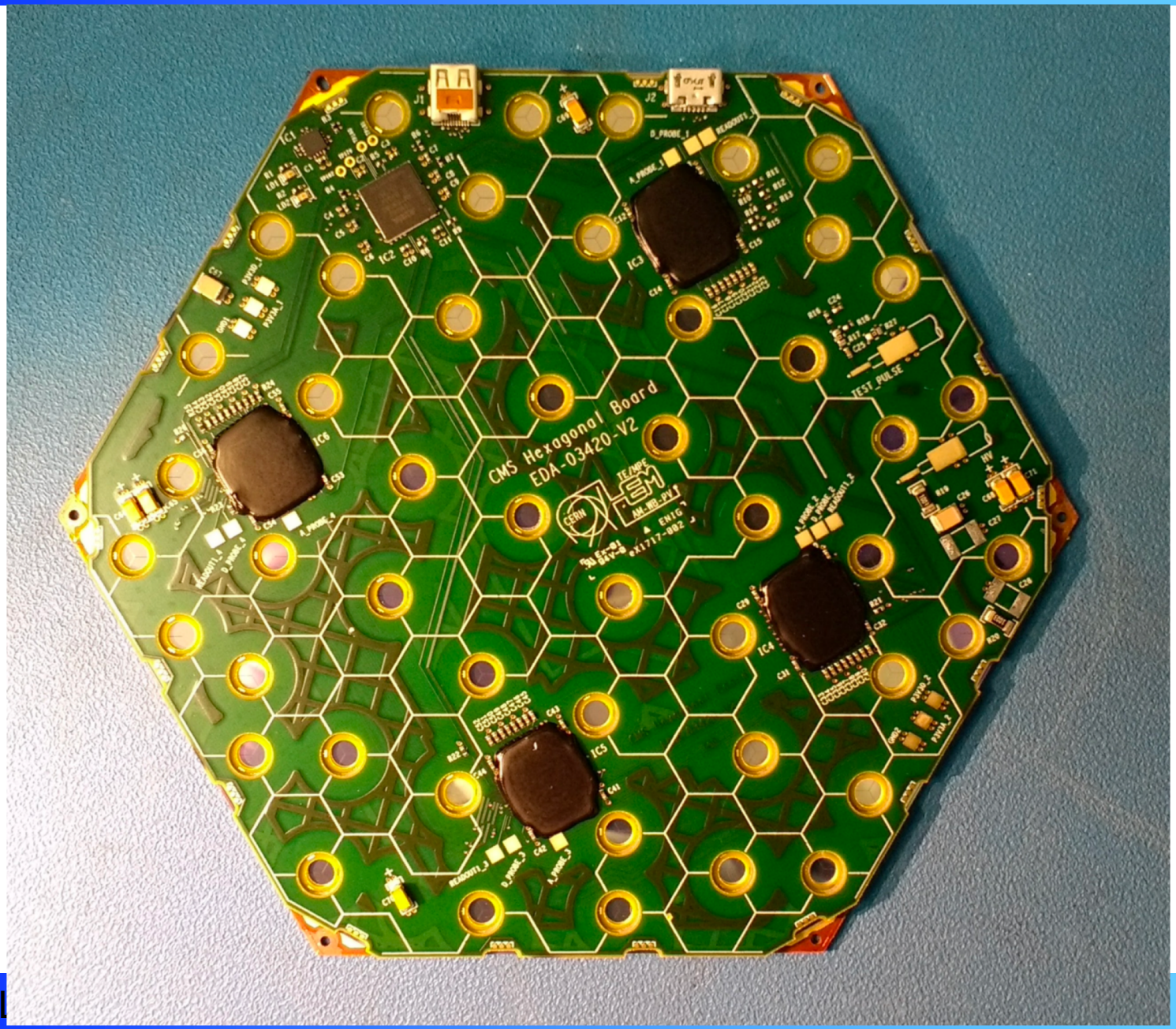


总结

- HGCal R&D:
  - 围绕硅模块，开展Si sensor，PCB，模块性能，宇宙线和束流测试等研究
  - 项目进展顺利
- 洁净间：4号厅160平米，准备建设
- HGCal实验室设备: 正在申请支持
- HGCal Core contribution:
  - 未来经费支持?
- 参加人员：
  - Physicist: 张华桥，廖红波，刘勇，王峰（博士后), 李秉桓 (博士)
  - Engineer: 曹学雷，顾虞栋，李鲜，刘晓静，孟斌，孙亮，张春雷，张万昌

Plan:

2018: Clean room ready → 2019: main MAC equipment ready → 2020: training & site qualification → 2021:start mass production


CMS Hexagonal Board
EDA-03420-V2
TEST_PULSE

中国高粒度量能器项目目标

目标： 部分掌握高粒度量能器设计、建造。
跟进和填补空白，打破禁运。

- 课题四的子课题之一，研发阶段的经费为285万元人民币
- 1) 测试不同工艺的硅传感器性能,反馈给硅传感器生产公司,设计出符合高粒度量能器抗辐射,能量和时间分辨要求的硅传感器。
  - 和欧洲核子中心合作，一博士常驻欧洲核子中心，学习相关的技术
- 2) 开展硅模块组装的研究,设计出满足硅模块厚度要求和质量控制的方案,为实验束测试提供硅模块, 为后续量产提供方案。
  - 和美国加州大学圣巴巴拉分校合作
- 3) 参与实验样机的实验束测试,通过对高粒度量能器性能的研究,改进硅传感器的设计,硅模块的组装,模拟性能研究等。
  - 参与实验束装置的组装，值班，分析。在费米实验室，欧洲核子中心分析实验束数据等

2016-2017: 高粒度量能器采购清单;高粒 度量能器硅原型机模块组装概念设计流程图
2017-2018: 高粒度量能器原型机照片;高 粒度量能器原型机 MIP 初步测量 结果;