



中国科学院高能物理研究所

Institute of High Energy Physics Chinese Academy of Sciences

ATLAS实验高颗粒度高时间分辨探测器 ATLAS High-Granularity Timing Detector (HGTD)

梁志均

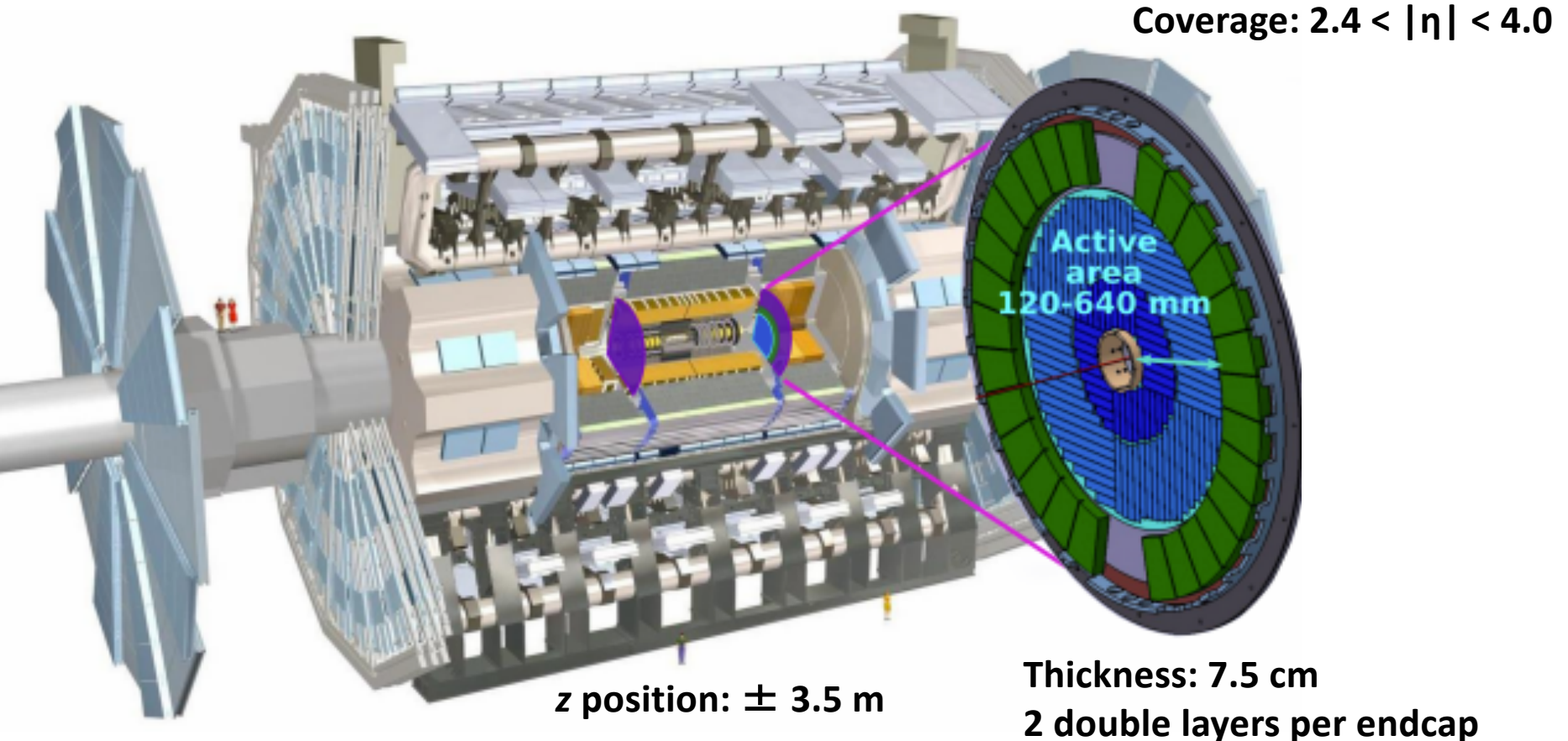
Zhijun Liang

中国科学院高能物理研究所

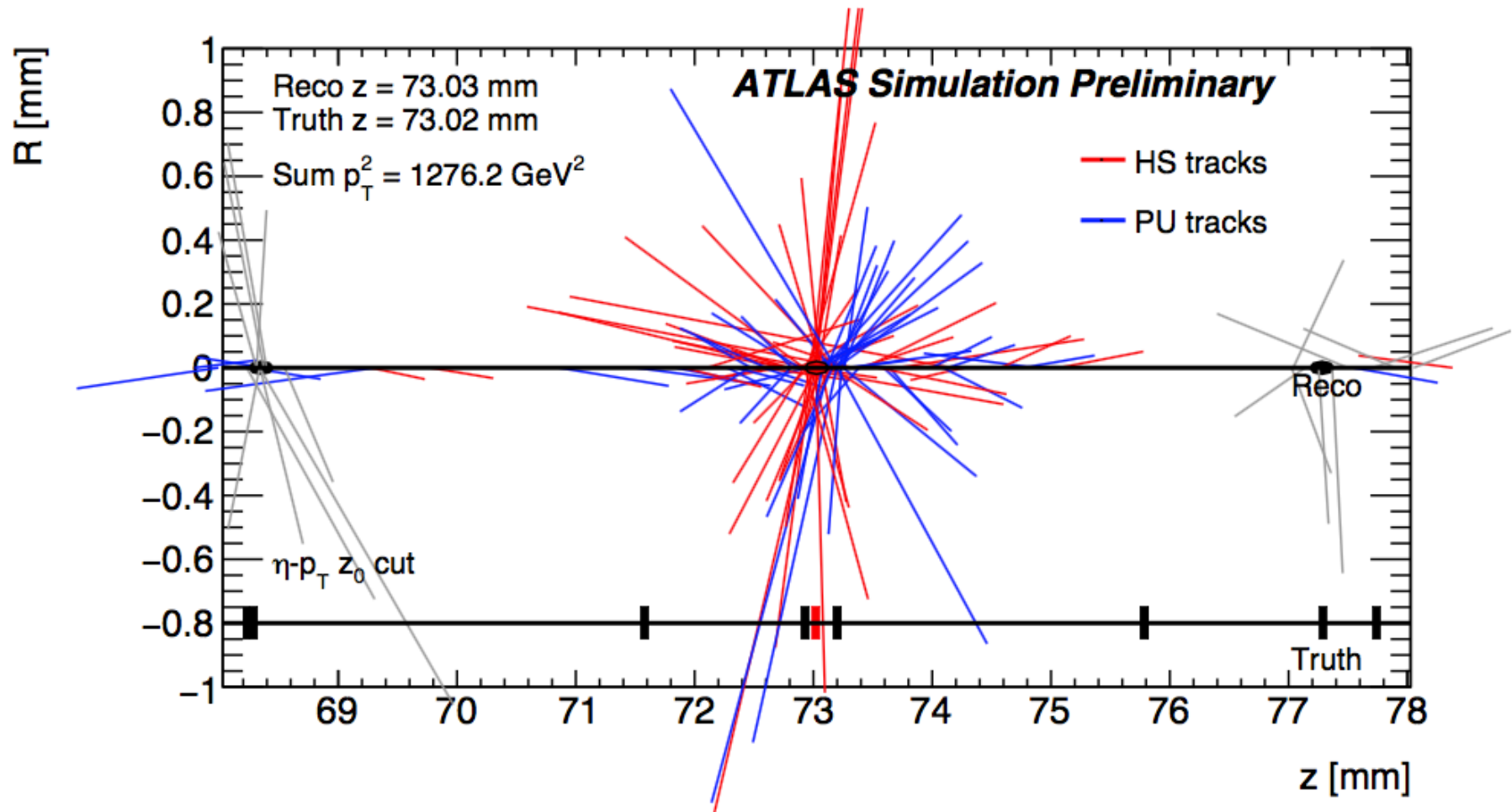
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ATLAS实验高颗粒度高时间分辨探测器

- **ATLAS will upgrade endcap calorimeter in 2026**
 - High-Granularity Timing Detector (HGTD)
 - LGAD will be used for **timing measurement (30ps)**
 - **6.4m² area silicon detector**

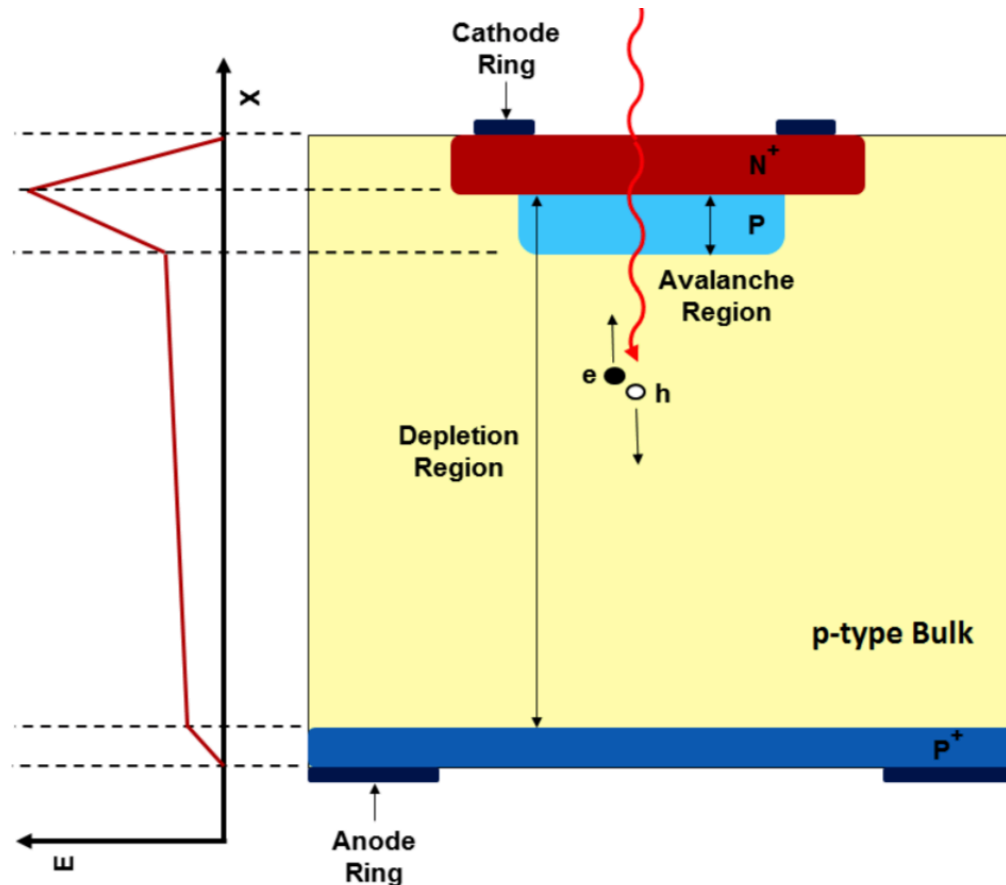


- **Pileup is the major challenges at HL-LHC**
 - **Track from different vertexes close in space, but well-separated in time**



低增益雪崩放大传感器 (LGAD)

- **Low-Gain-Avalanche-detector (LGAD)**
 - Compared to APD and SiPM, LGAD has lower gain (~ 10)
 - high drift velocity, thin active layer (fast timing)
 - High S/B, no self-triggering

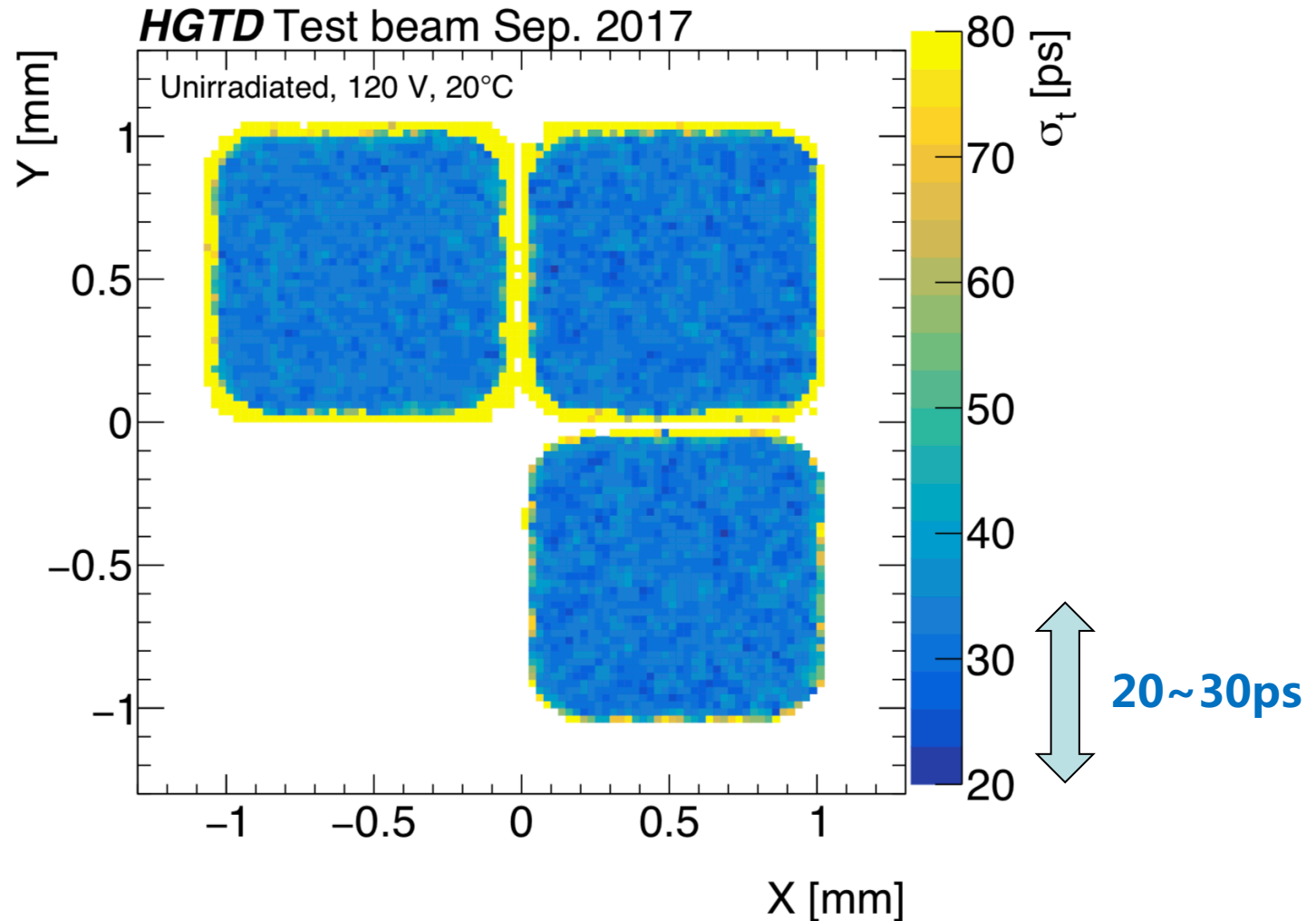


LGAD Foundry:

- HPK (Japan)
- CNM(Spain)
- FBK (Italy)...

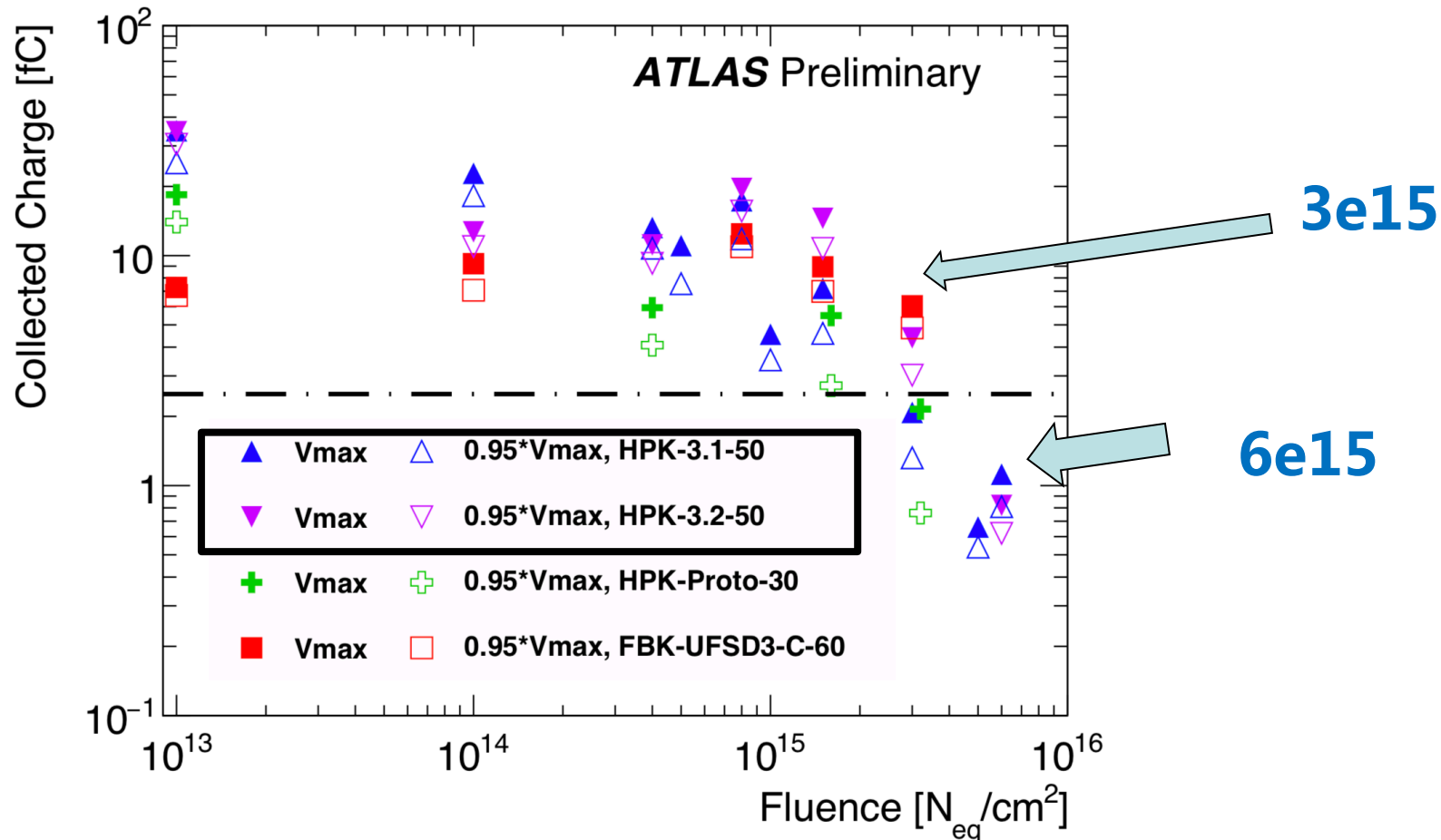
LGAD传感器的时间分辨率

- Timing resolution :20~30ps in test beam
- IHEP group contributed to test beam in last year.



LGAD抗辐照研究情况

- **Non-ionization dose (NIEL)**
 - Survive after $3e15$ n_{eq}/cm^2 fluence
 - Need to improve irradiation hardness for $6e15$ n_{eq}/cm^2
- **Total ionization dose (TID) effect to be studied**



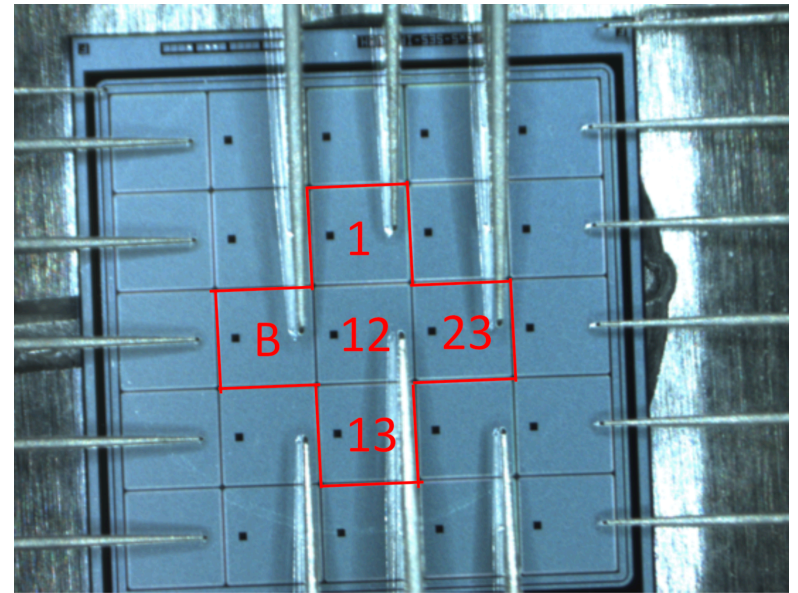
LGAD抗辐照机制

- IHEP have set up a sensor testing system
 - Thanks to probe station from Key lab
 - Test Leakage current and capacitance of HPK and CNM sensors

利用国重的探测台搭建探针卡测试系统

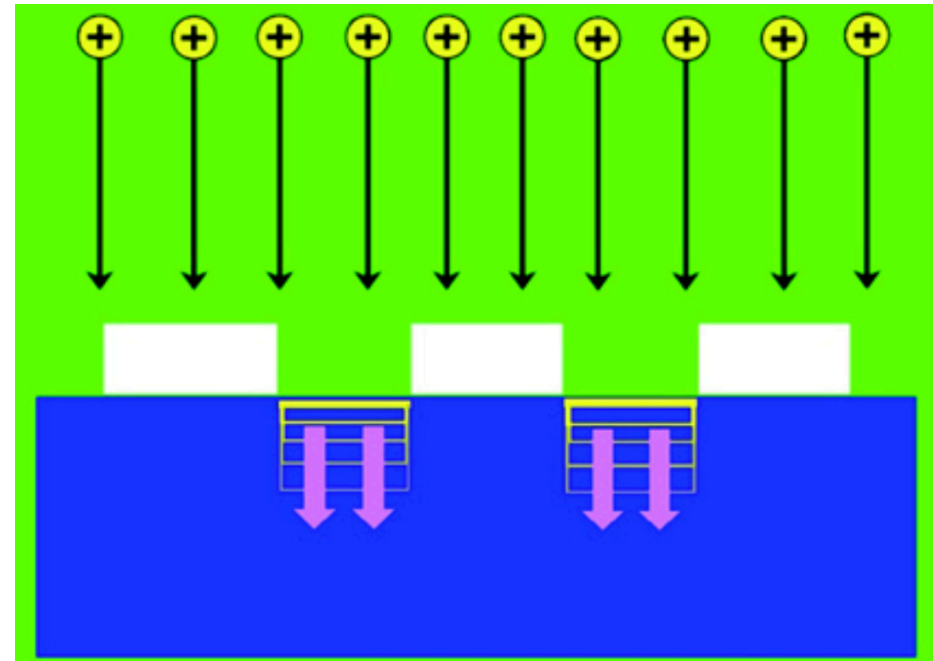
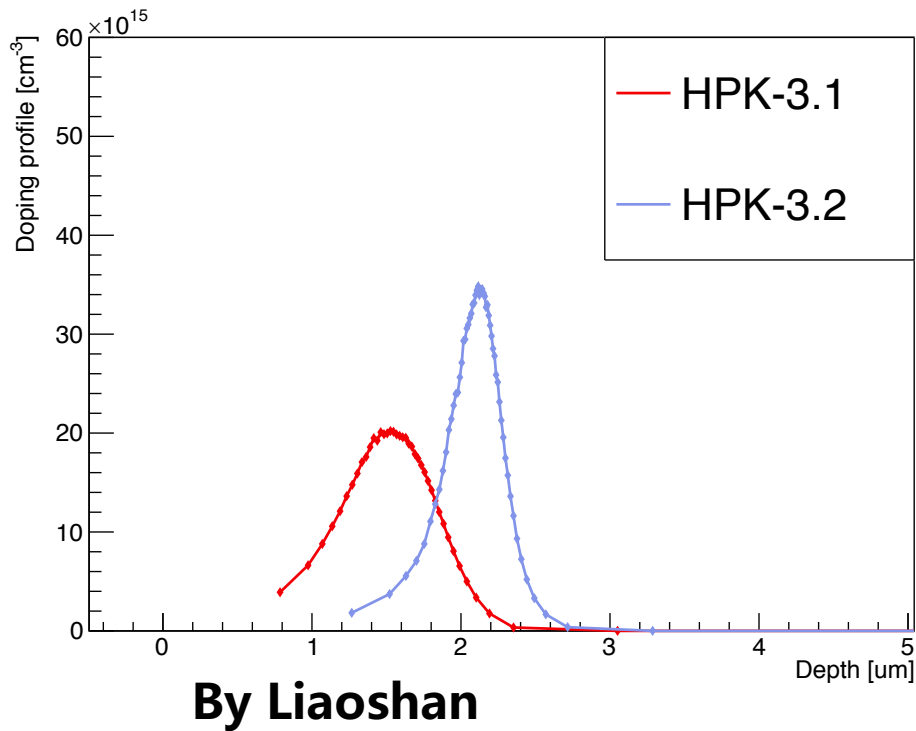


By Ryuta & Liaoshan



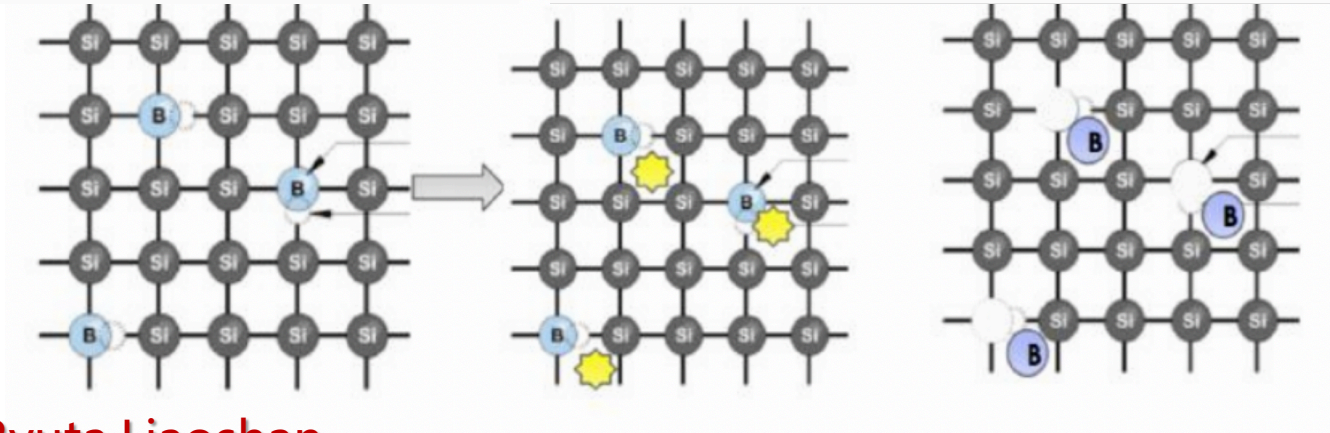
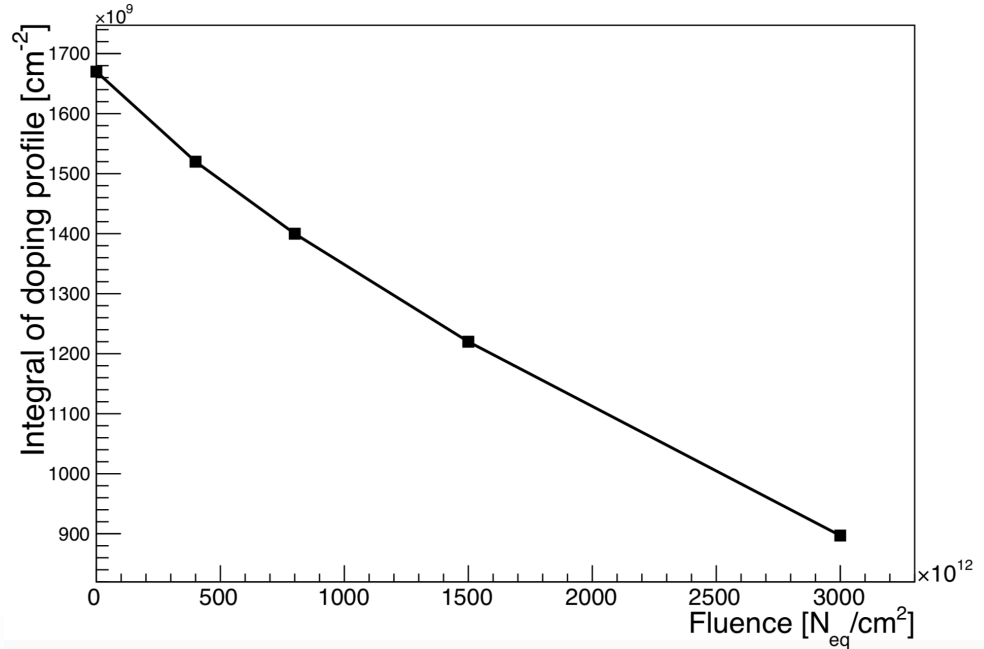
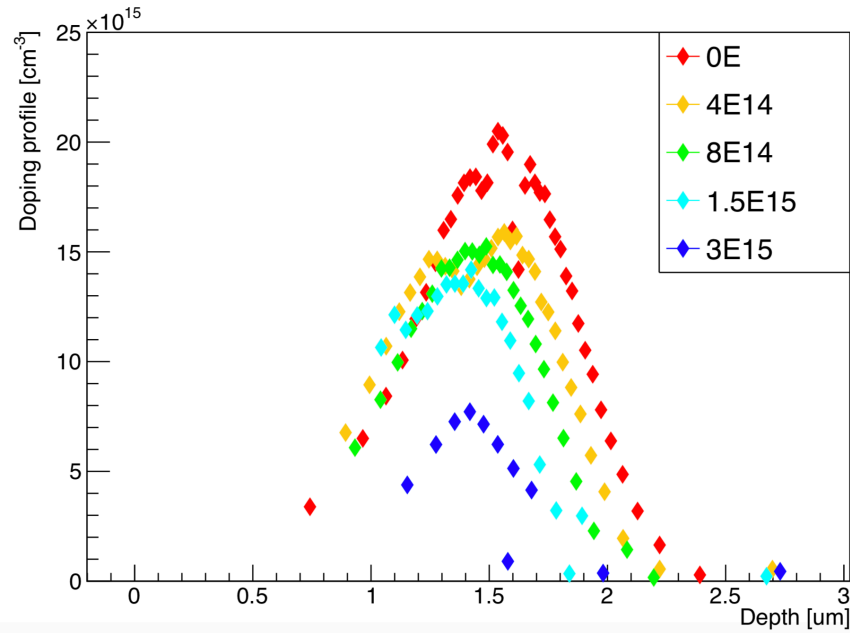
LGAD抗辐照研究情况

- Measure doping profile of two type doping in HPK sensor :
 - Type 3.2 has better irradiation hardness
 - Deeper implantation improves irradiation hardness



LGAD抗辐照研究情况

- First time to confirm acceptor removal effect of LGAD in C-V



By Yuhang, Ryuta, Liaoshan

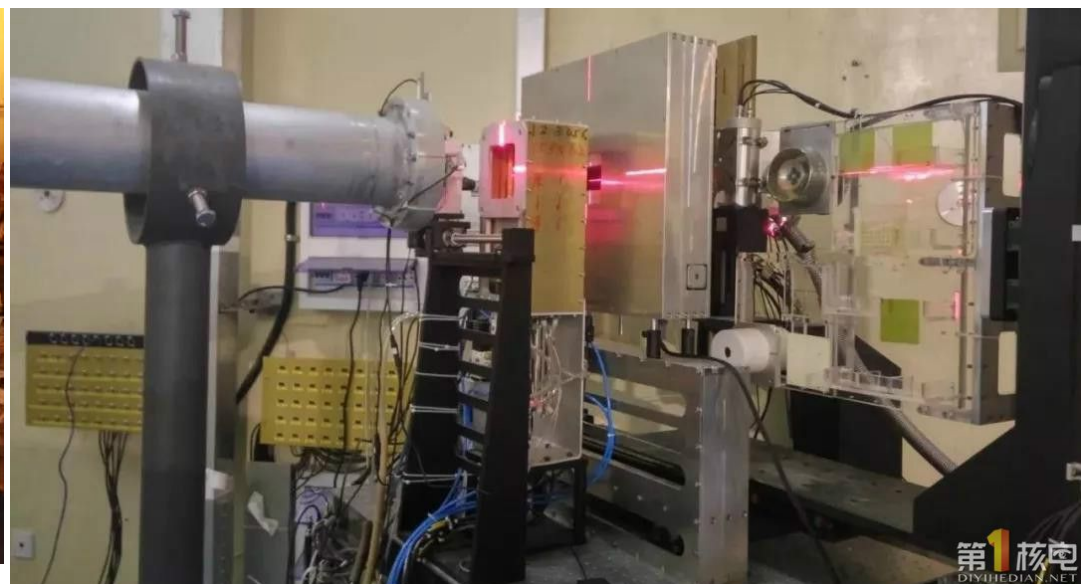
LGAD抗辐照研究计划: 电离辐照效应

- Total ionization dose (TID) effect is one major R & D next step
- IHEP will take leading role in this TID study
- MultiRad 160 X ray irradiator in IHEP
 - Maximum dose rate 250Gy per minute
 - reach 4.7MGy TID in about two weeks
 - 1 kGy, 10 kGy, 100 kGy, 1 MGy, 5MGy



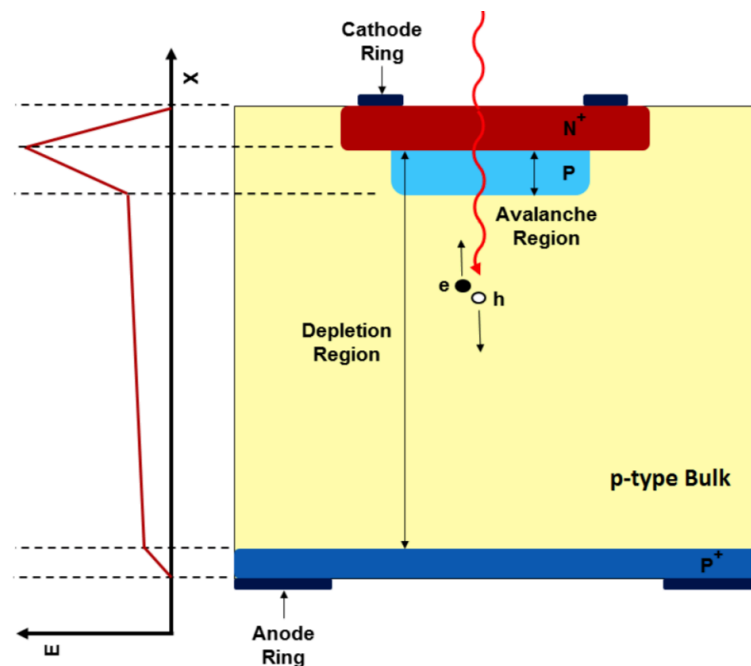
LGAD抗辐照研究计划: 非电离辐照效应

- 100MeV proton irradiation can be done in CIAE, Beijing.
 - Can reach 5.1×10^{15} fluence in about 8~10 hours
 - Possible to do I-V and C-V online during irradiation (Can stop the run anytime)
 - In near future, >1GeV proton beam in China Spallation neutron source
- 100MeV proton cyclotron in CIAE Station for irradiation in CIAE



LGAD传感器国产化研究

- LGAD sensor with Epitaxial layer wafer (高阻外延片)
 - Collaboration with Beijing Normal University.
 - Easier and cheaper to get wafer with Epitaxial layer
 - Lower Resistivity in Epitaxial layer (300 Ohm.cm)
- “high resistance wafer” + “low resistance “ bonded wafer (键合片)
 - collaboration with Tsinghua University
 - Expensive and hard to buy bonded wafer (Kewei’s talk later)



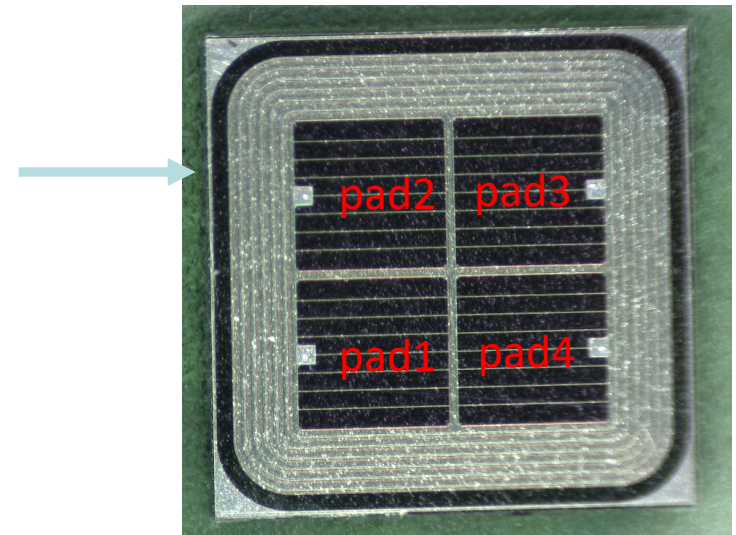
首批国产LGAD传感器

– April 2019 , First batch of domestic LGAD with Epitaxial layer

- Collaboration with Beijing Normal University (NDL is foundry for SipM)
- First batch LGAD sensor fabricated. (~100 2x2 sensors)
 - Thickness of epitaxial layer: 33um
 - epitaxial layer Resistivity: 300 Ohm.cm



Two type of LGAD sensors
BV170-30-B, BV60-50-B



NDL can provide reliable and cost effective SiPMs with typical delivery time from 1 week to 3 months.

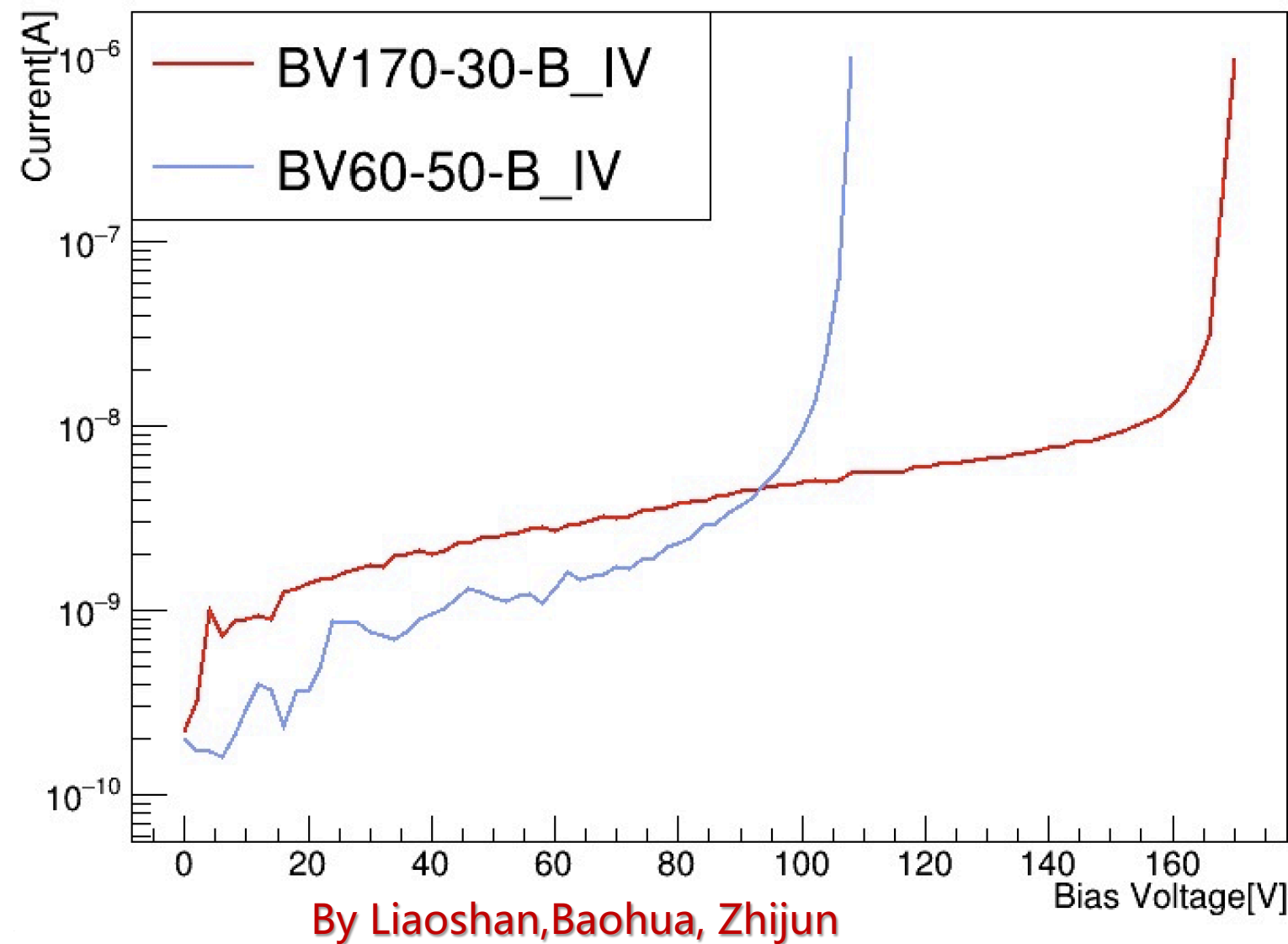
Novel Device Laboratory (NDL)
Address: XueYuan Nan Lu No.12
Hai Dian District, Beijing, China, 100875
Tel: +86-10-62207419, Fax: +86-10-62207419
Email: info@ndl-sipm.net

Photoelectric Instrument Factory of Beijing Normal University
Address: 1st floor in block B of Dormitory 4 Xin Wai Da Jie No.19, Hai Dian District, Beijing, China
Tel: 010-58807630
Email: 58807630@163.com
Web: <http://www.peifbnu.com/plus/view.php-aid=72.html>



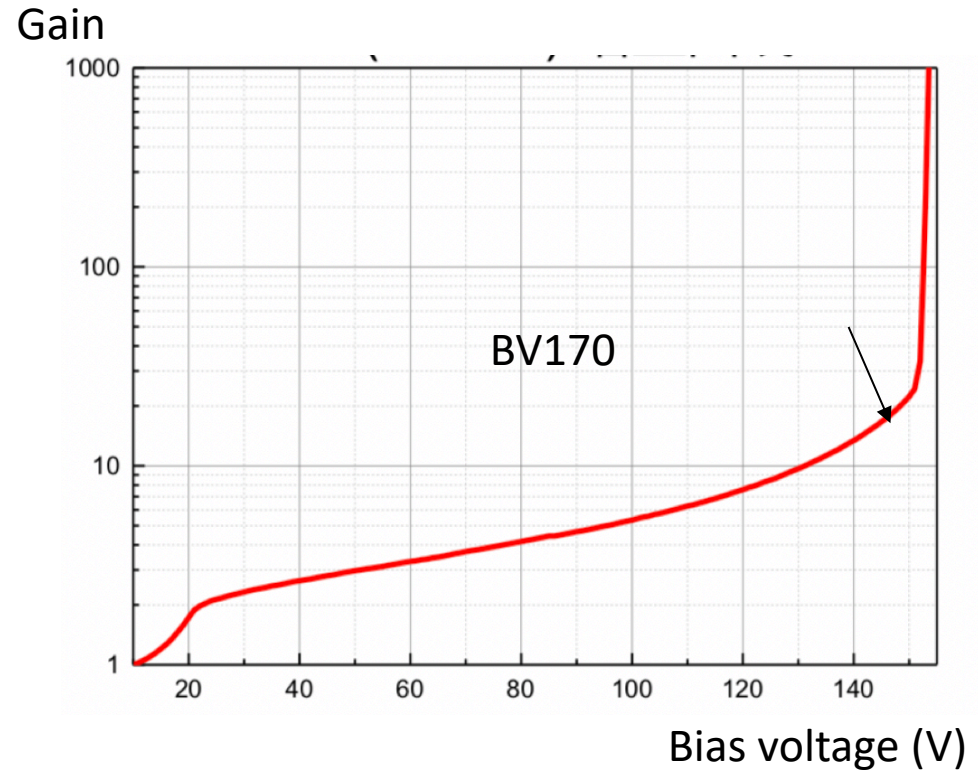
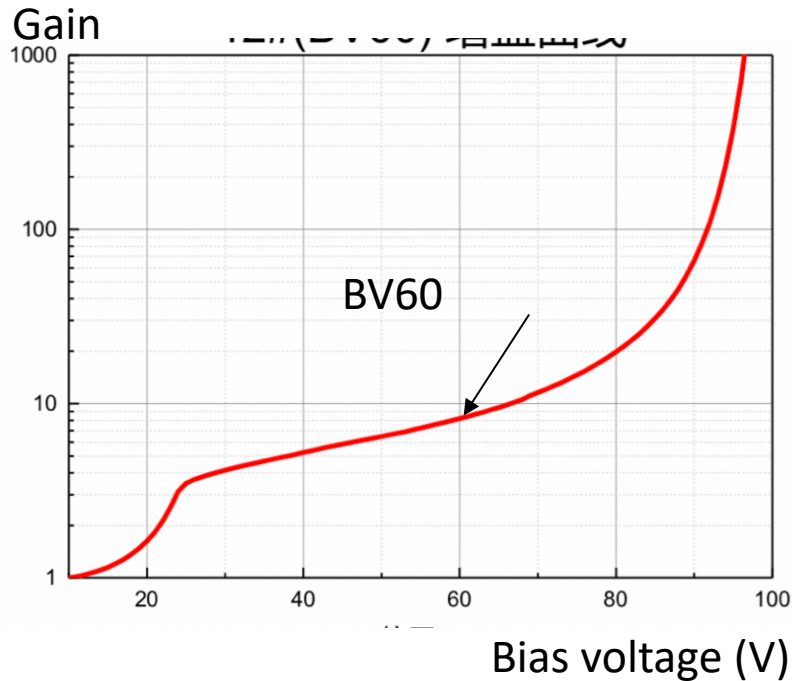
首批国产LGAD传感器: 测试结果

- Two type of NDL sensors (BV170 and BV60)



首批国产LGAD传感器: 测试结果

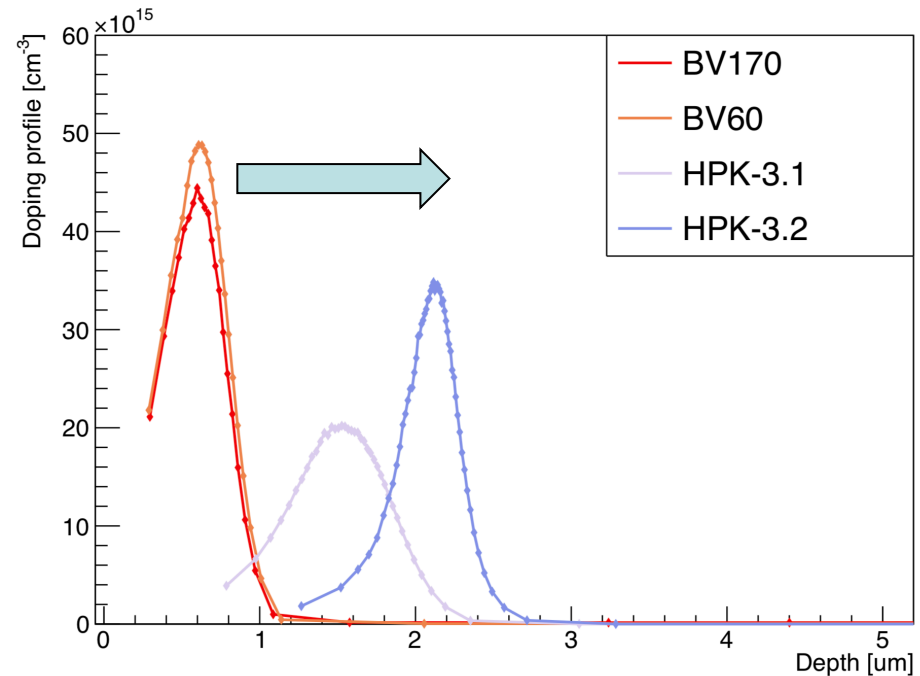
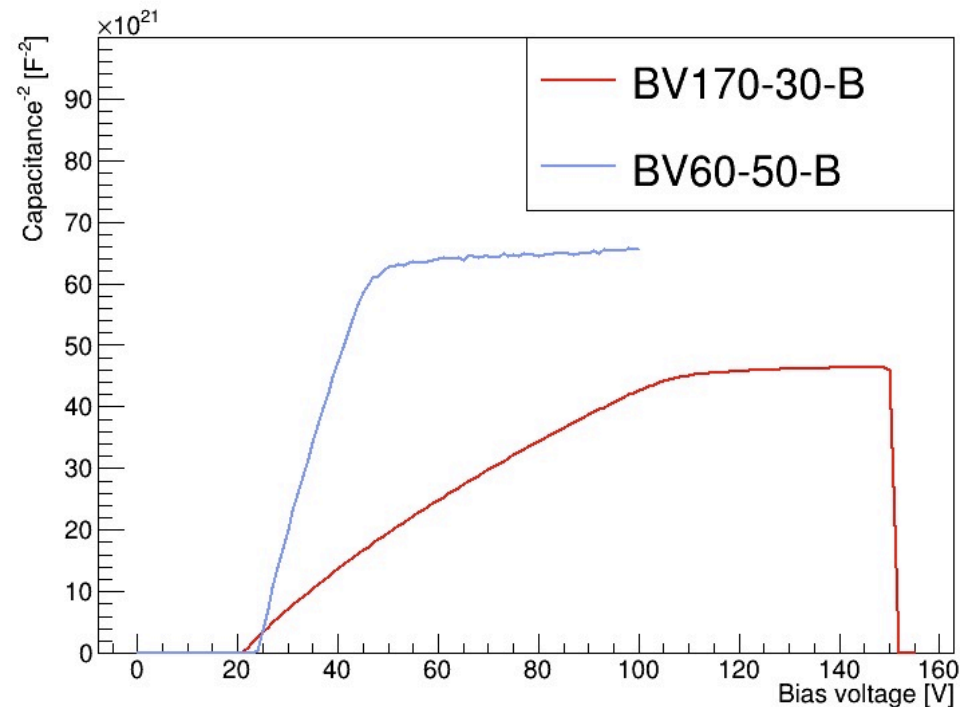
- Two type of NDL LGAD sensor (gain=10 for working voltage)



By Liaoshan, Baohua, Zhijun

首批国产LGAD传感器: 测试结果

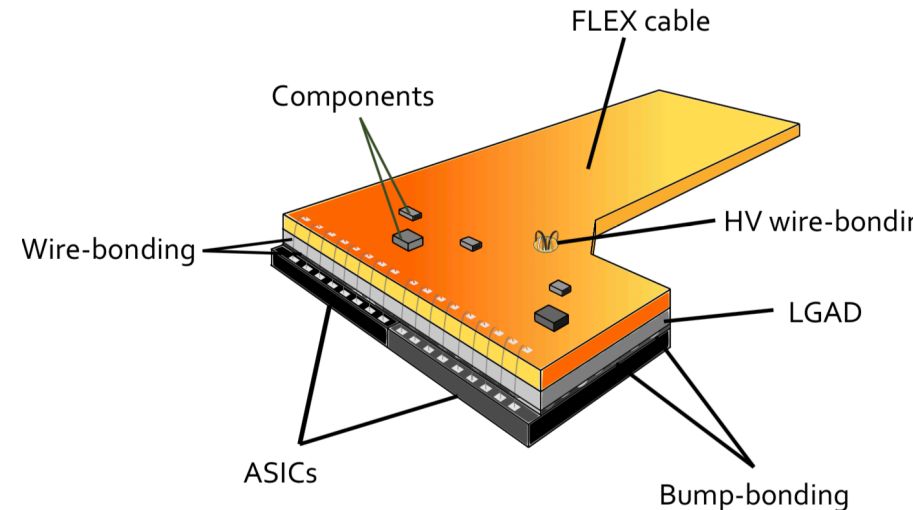
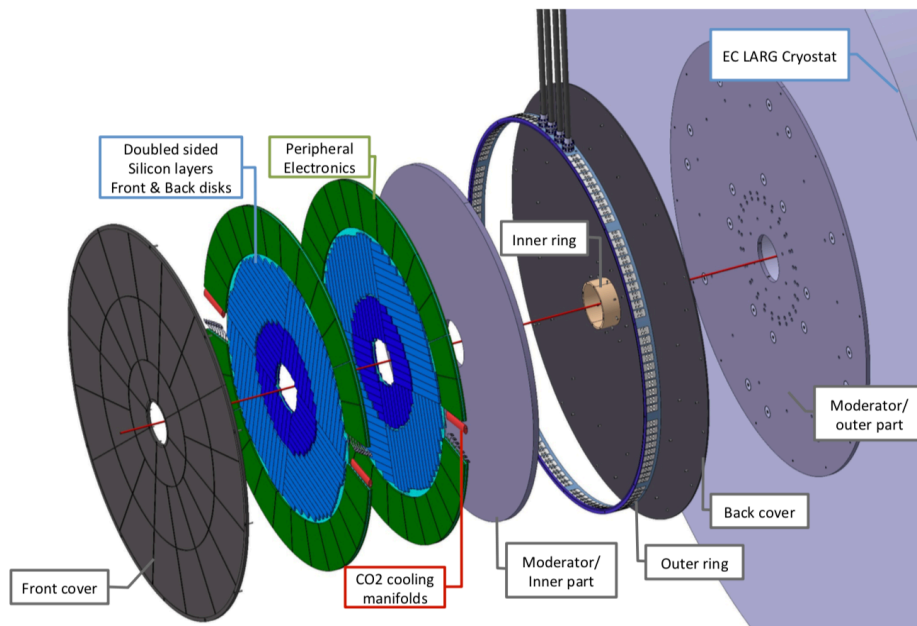
- **BV60 depleted at 50V , BV170 depleted at 110V**
- **Doping depth for p+ layer is lower compared to HPK**
 - **try deeper p doping in next submission in May**



By Liaoshan, Baohua, Zhijun

HGTD的模块研制

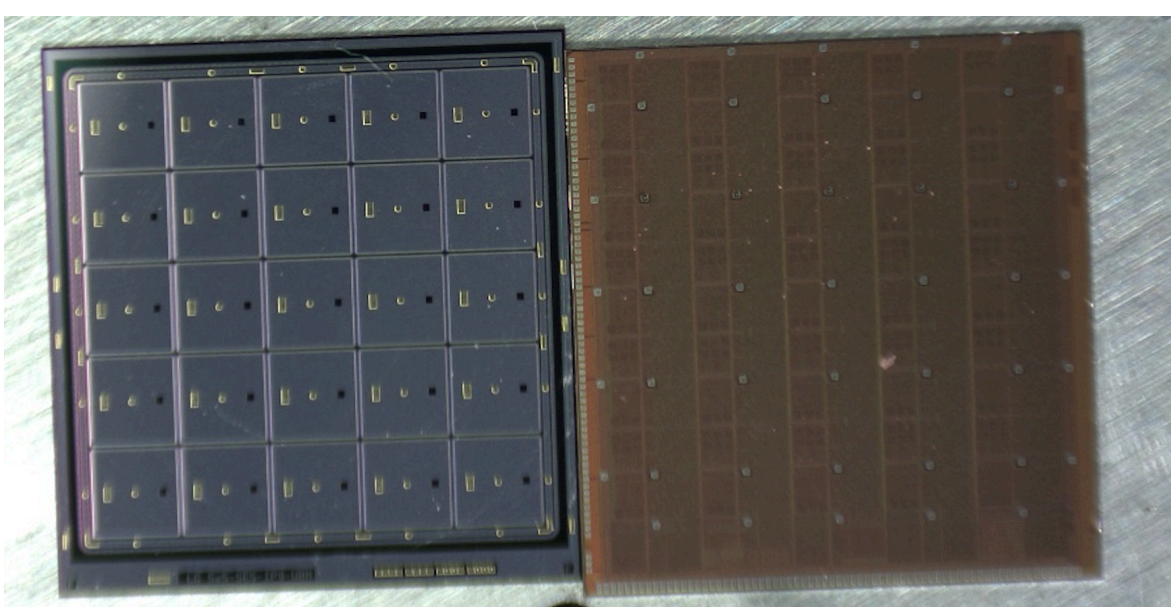
- ~8000 modules and 6.4m² silicon detector in HGTD project
- ATLAS China group will have significant contribution in HGTD module
 - One of key issue is bump bonding between ASIC and sensor
 - IHEP has done some R & D on this.



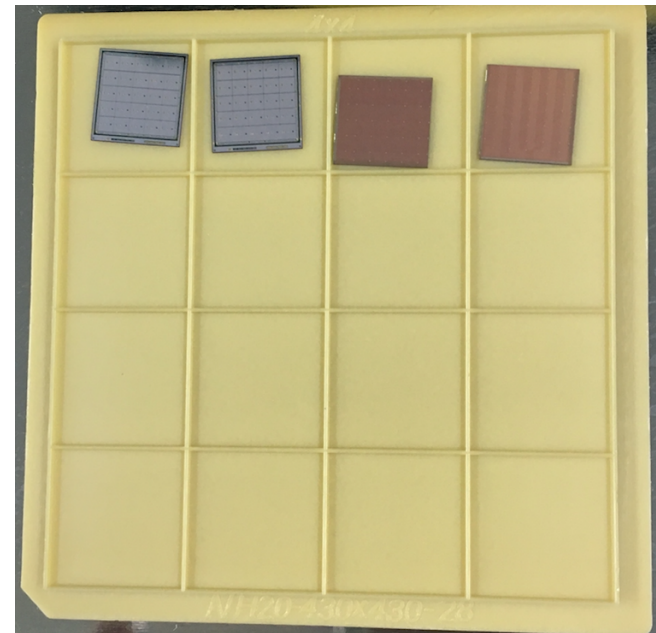
倒装焊的研究

- Two company identified (both are top 10 packaging company)
 - The National Center for Advanced Packaging (NCAP, 华进)
 - <http://www.ncap-cn.com/en/index.aspx>

HPK 5x5 Sensors and Altirco1 chip in IHEP



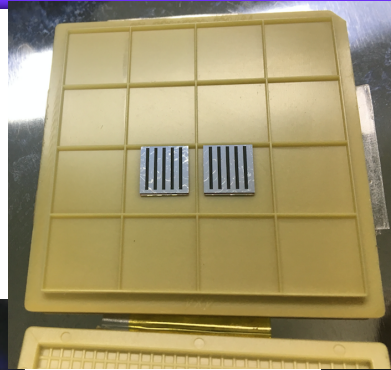
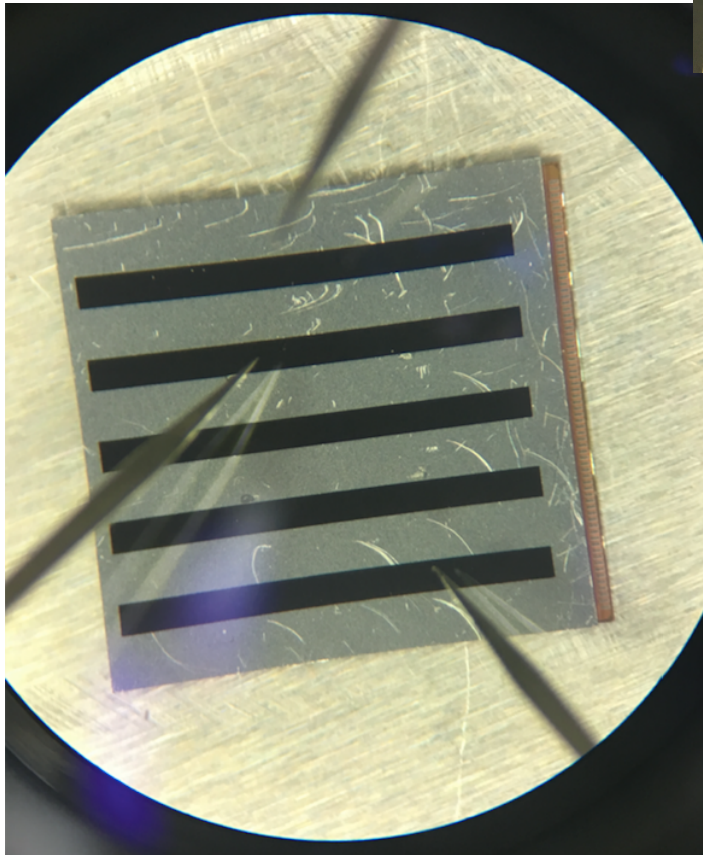
5x5 sensor and ASIC



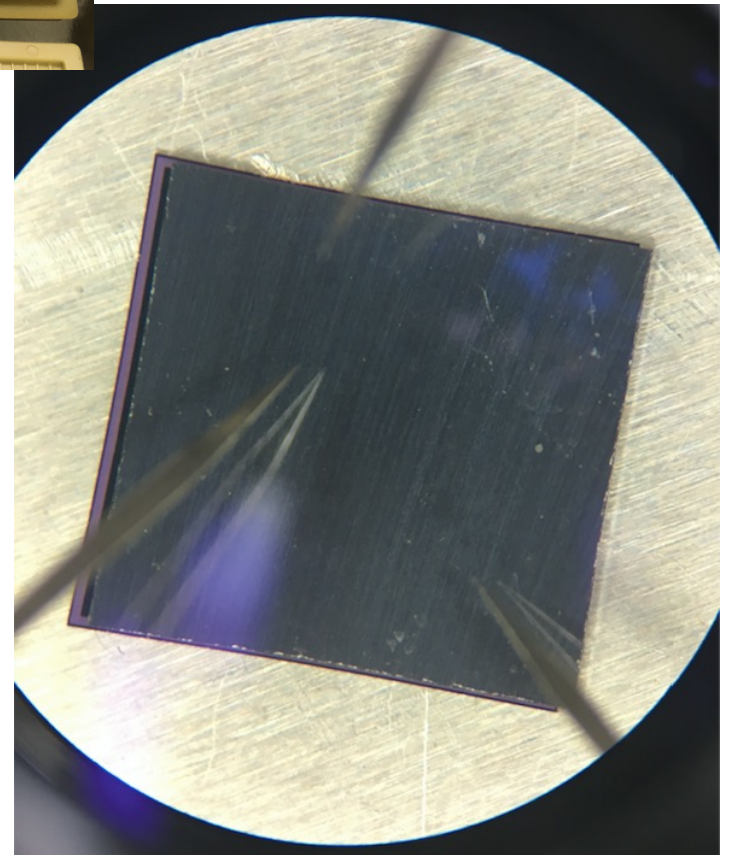
By Zhijun & Liaoshan

倒装焊的研究

Sensor side



ASIC side



总结

- HGTD的LGAD传感器研究
 - 辐照机制研究
 - LGAD传感器国产化研究(首批国产LGAD传感器)
- HGTD读出芯片ASIC
 - 计划参与抗辐照数字电路设计
 - 电离辐照后性能研究
- HGTD的模块研制
 - 在国内完成倒装焊
- 非常感谢核探测与核电子学国家重点实验室支持！

Outline

- Irradiation facility in China for HGTD sensor
- Test result of irradiated sensors
- LGAD Sensor from Chinese foundry
- Question about the LGAD sensor UBM

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