2019年卓越中心“拔尖人才”评审

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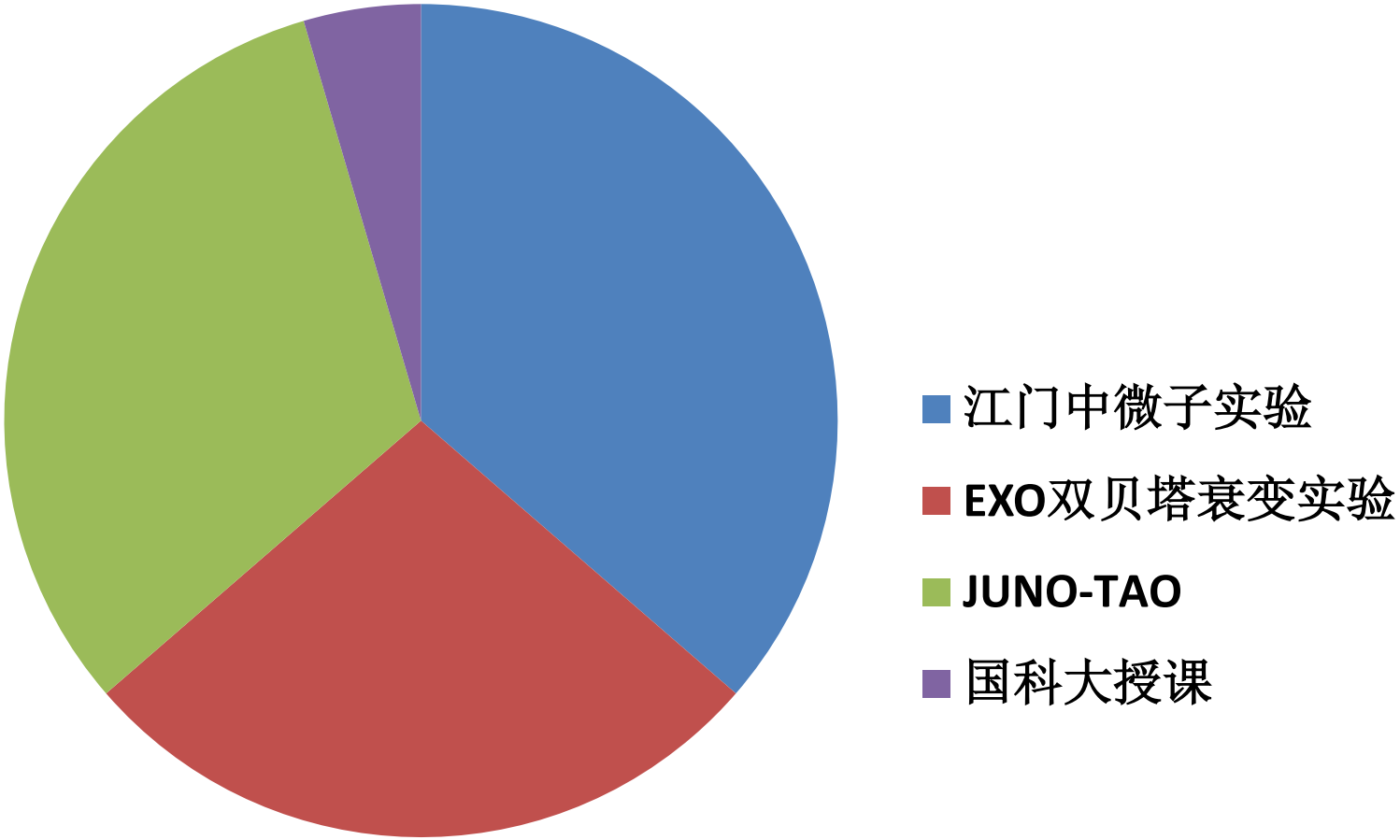
高能物理研究所

2019年12月07日

时间分配

2018.12 ～ 2019.12



主要工作进展

- **JUNO探测器模拟**
  - **Co-L3 manager (曹国富/邓子艳)**
- **SiPM性能表征**
  - **VUV波段 -- nEXO实验**
  - **可见光波段 -- TAO实验**
- **TAO探测器SiPM读出方案**
- **Mini-nEXO液氙TPC**
- **硅基转接板研发**

JUNO探测器模拟组

- **更新探测器几何至最新**
  - PMT排布，刻度管，有机玻璃支撑结构
- **改进Cerenkov过程模拟**
  - 能够处理折射率对光子波长的复杂依赖关系，例如江门液闪的折射率
- **升级Geant4.9.4到Geant4.10.4**
  - 大量的validation工作，不同能区、不同粒子种类
  - 历时半年完成G4版本升级。
- **电子学模拟优化与改进**
  - 应用JUNO最新PMT测试数据到电子学模拟中
  - 优化本底混合算法，运行速度提高10倍以上
  - 触发算法模拟 -- arXiv:1912.01864, submitted to JINST
- **批量刻度数据产生**
  - 研究刻度策略
  - 检验模拟流程

- **液闪VUV波段折射率**
  - **对理解JUNO能量分辨率和能量非线性至关重要**
  - **与成光所合作**
  - **基于高能所VUV测试系统实验平台**
  - **计划申请2020年核探测与核电子学国家重点实验室开放课题**

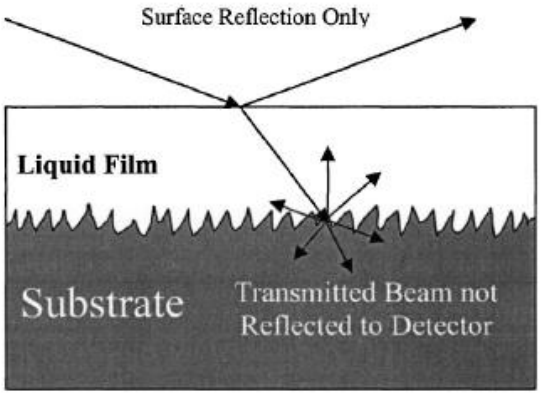
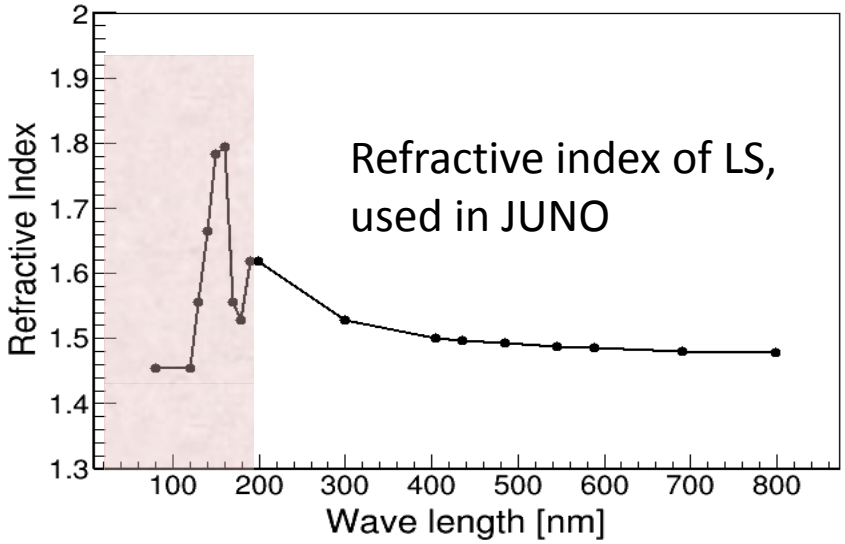
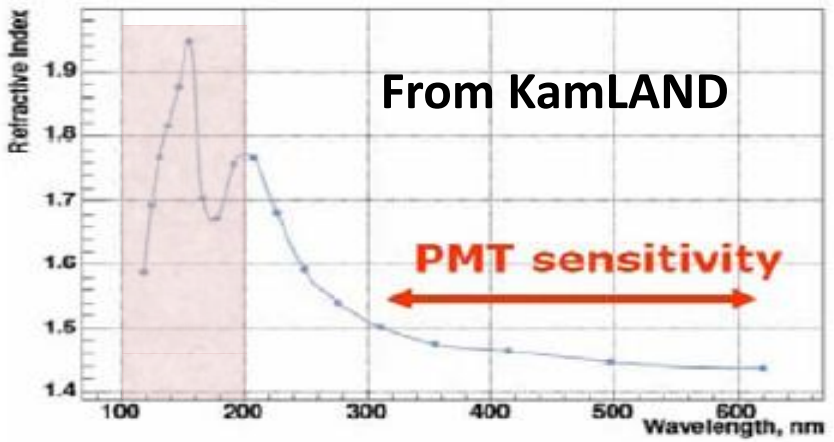


FIG. 1. Geometry of the rough surface technique for liquid measurements. The rough liquid–substrate interface scatters incident light, leaving only the reflection from the smooth upper surface. This is equivalent to a measurement of a bulk liquid sample. The rough surface also serves to slow or prevent fluid flow, allowing the sample to be mounted either horizontally or vertically for measurement.

[DOI: 10.1116/1.1813455]





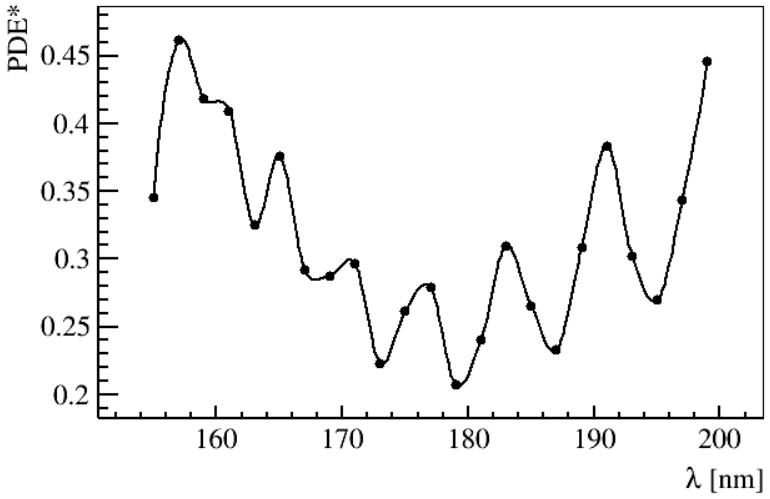
❄ SiPM在VUV波段反射率

罗凤娇，曹国富

- 理解nEXO能量分辨率的关键
- 指导SiPM ARC设计
- arXiv:1912.01841, submitted to IEEE Sensors

❄ SiPM绝对探测效率

- 提出用电流法测量SiPM绝对探测效率
- 降低SiPM效率误差从20%到~5%
- 一波三折，完成数据获取
- 分析修正因子



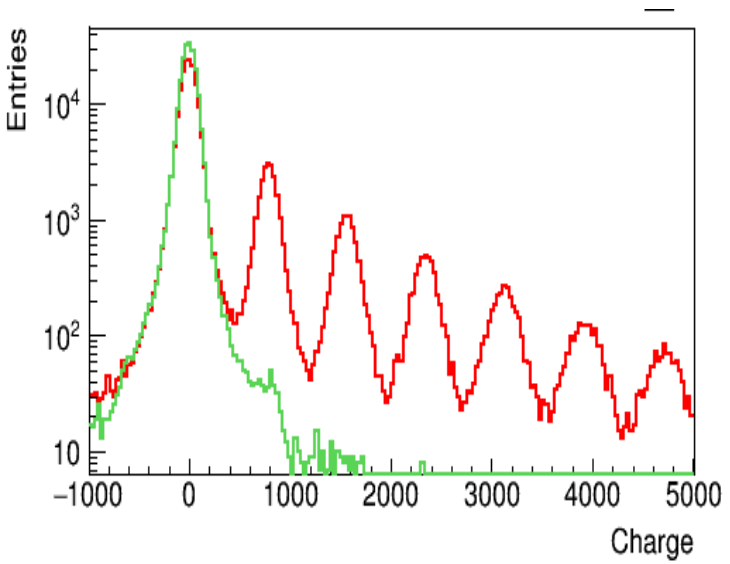
$$I_{light} = I^{*}_{light} - I^{*}_{dark} = N^{*}_{pe} \cdot G \cdot q = N^{SiPM}_{pe} \cdot R_{corr} \cdot G \cdot q = \frac{I_{PD}}{QE_{PD} \cdot q} \cdot PDE \cdot R_{corr} \cdot G \cdot q$$

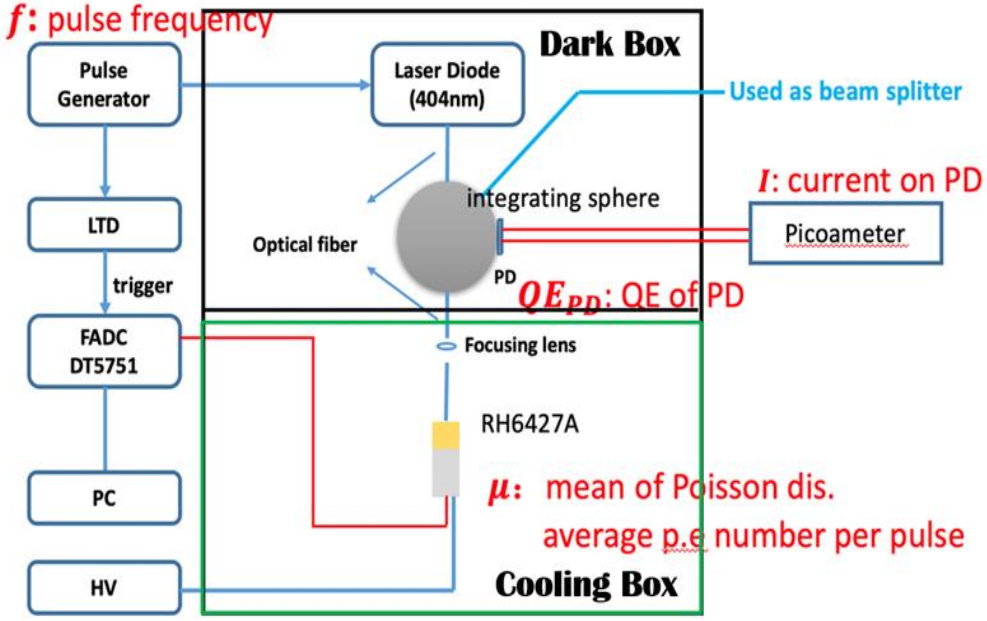
$$R_{corr} = (\mathrm{P}_{0\times T} + 2 \cdot \mathrm{P}_{1\times T} + 3 \cdot \mathrm{P}_{2\times T} + 4 \cdot \mathrm{P}_{3\times T} + ...) \cdot (1 + \overline{\mathrm{w}} \cdot \mathrm{P}^{1}_{AP} + \mathrm{P}^{2}_{AP})$$

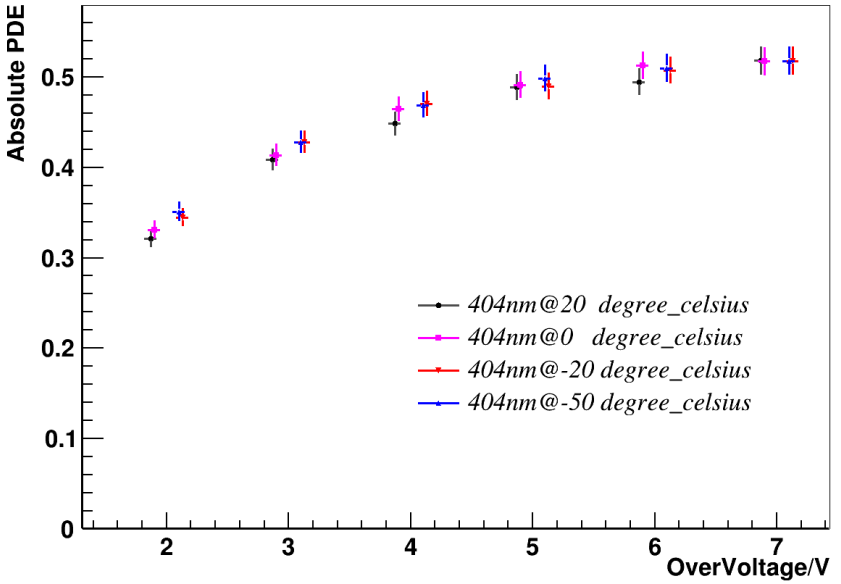
谢章权，曹国富

❄ SiPM性能表征

- 建立了一套SiPM性能测量系统
- 探测效率、光学串扰、暗噪声、后脉冲
- PDE角度响应和波长响应
- FBK和HPK两种感兴趣的SiPM
- 从常温到-50℃



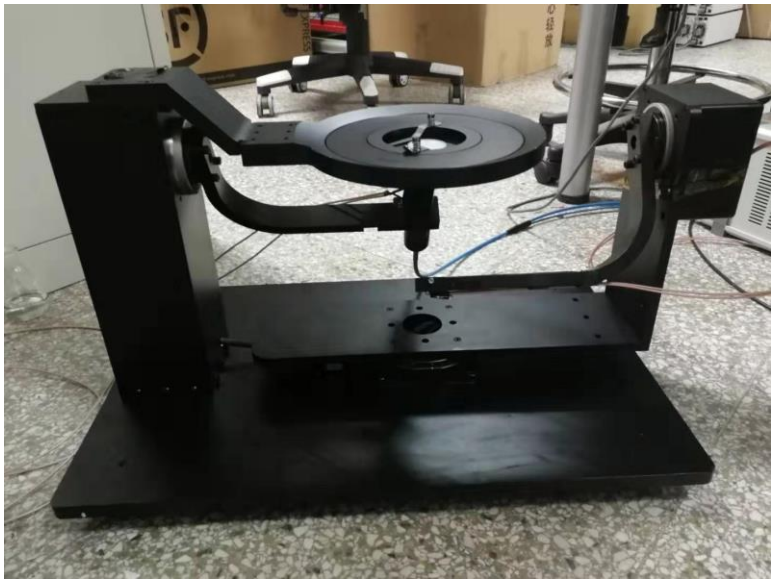


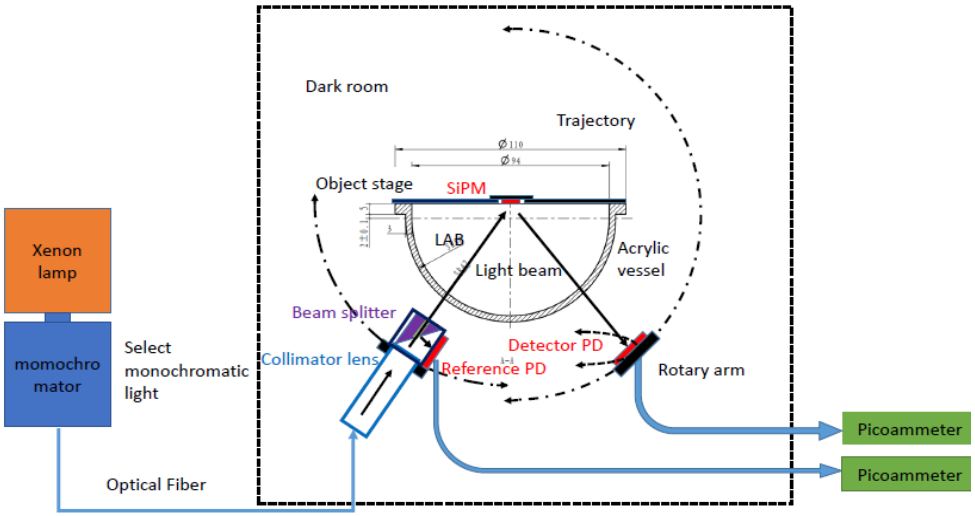


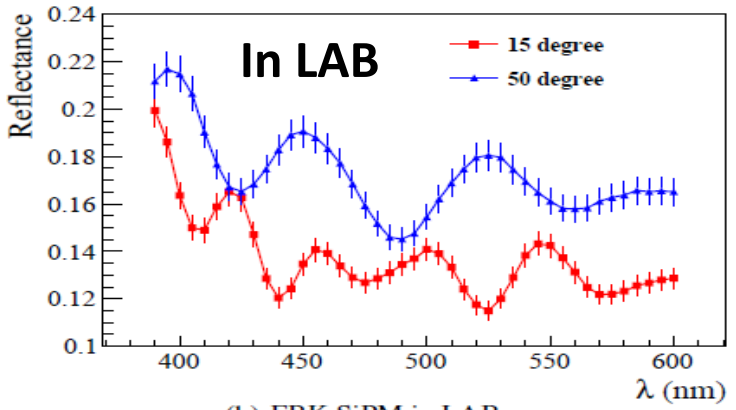
王维，曹国富

❄ SiPM在液体/空气(LAB)中的反射率

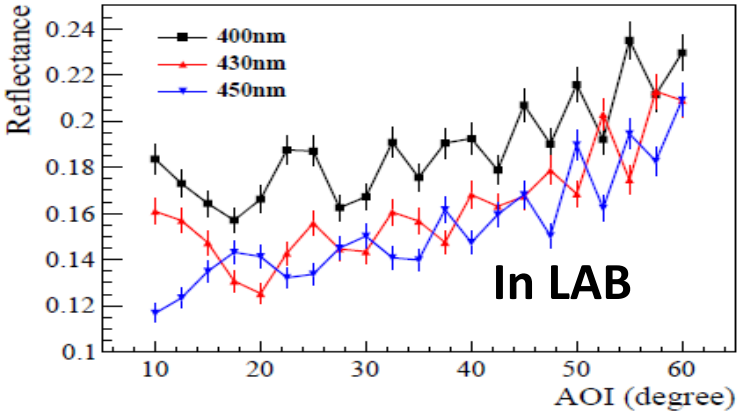
- 完成装置设计、加工和调试
- FBK和HPK两种感兴趣的SiPM
- R vs AOI, R vs λ
- 文章初稿基本完成



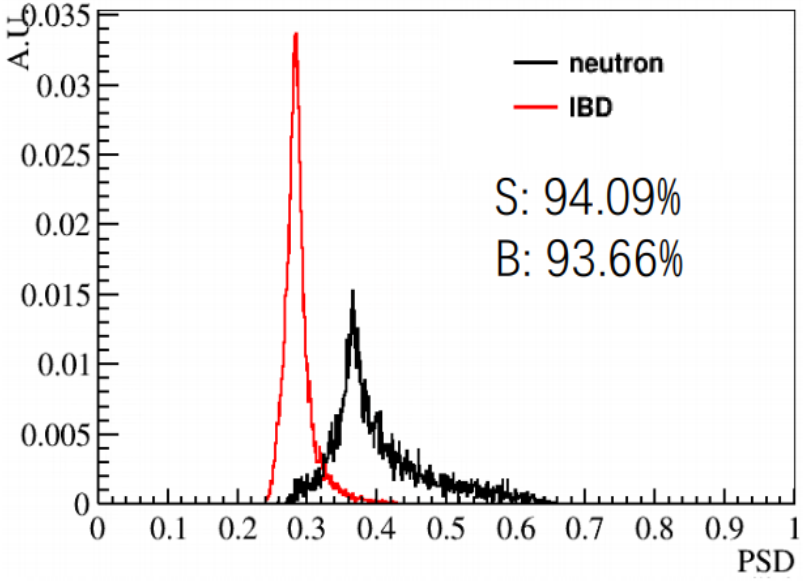




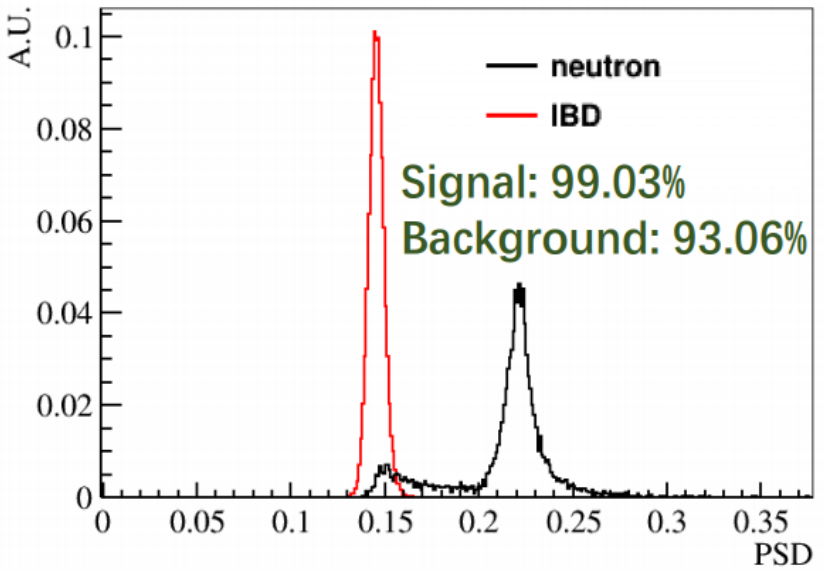
(b) FBK SiPM in LAB



- **两种读出方案**
  - **分立器件**
    - INFN和高能所(孙希磊)各有一套FEE方案
    - 都是基于DarkSide的前端电子学设计
    - 25 cm^2一个读出通道
  - **ASIC**
    - 颗粒度高 (140,000路)，具有更好的PSD和Cerenkov光探测能力
    - INFN尝试了CITIROC芯片，最近放弃了
    - 高能所测试了KLauS芯片 (18年首次与海德堡大学接触)



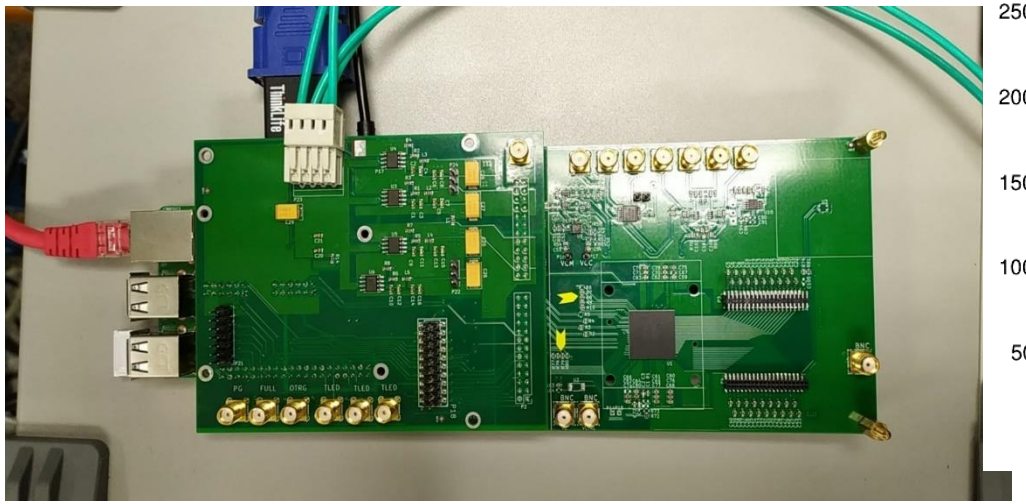
- **KLauS芯片测试结果非常乐观，基本验证了ASIC读出方案的可行性!**
  - **芯片测试过程中，得到了海德堡大学的大力支持**

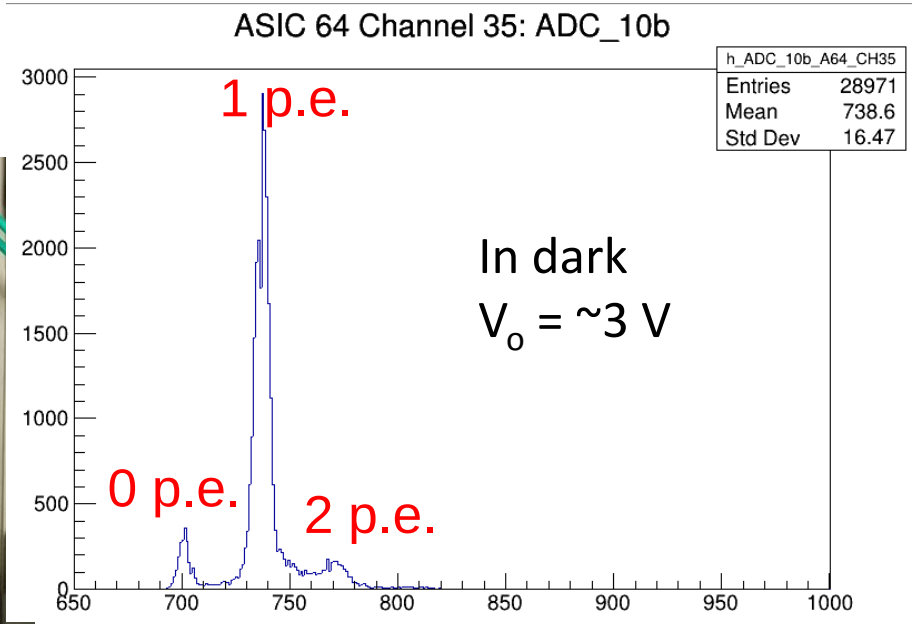


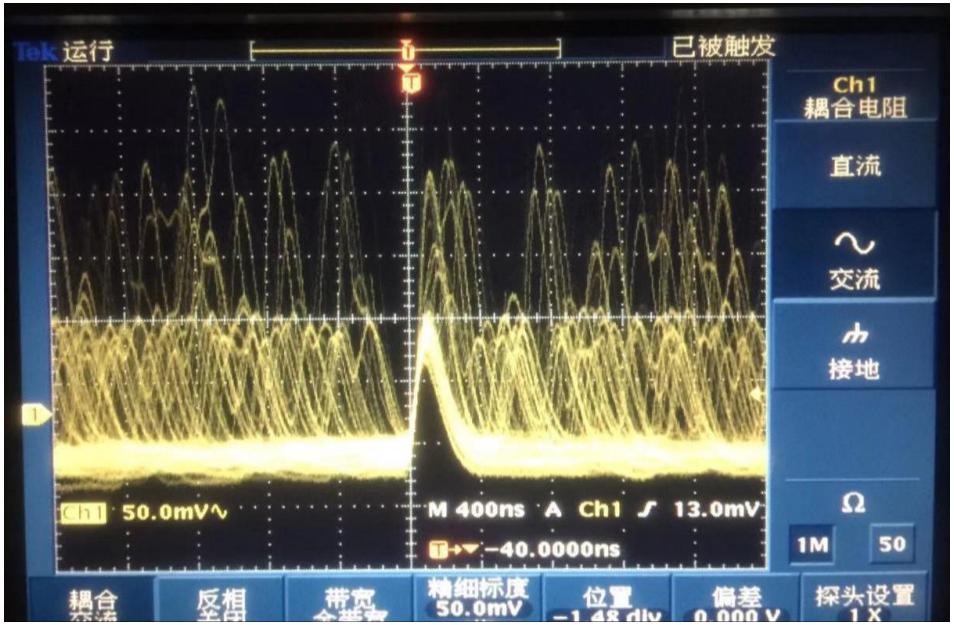
- **下一步：**
  - **细化读出方案设计**
  - **详细ASIC性能表征**

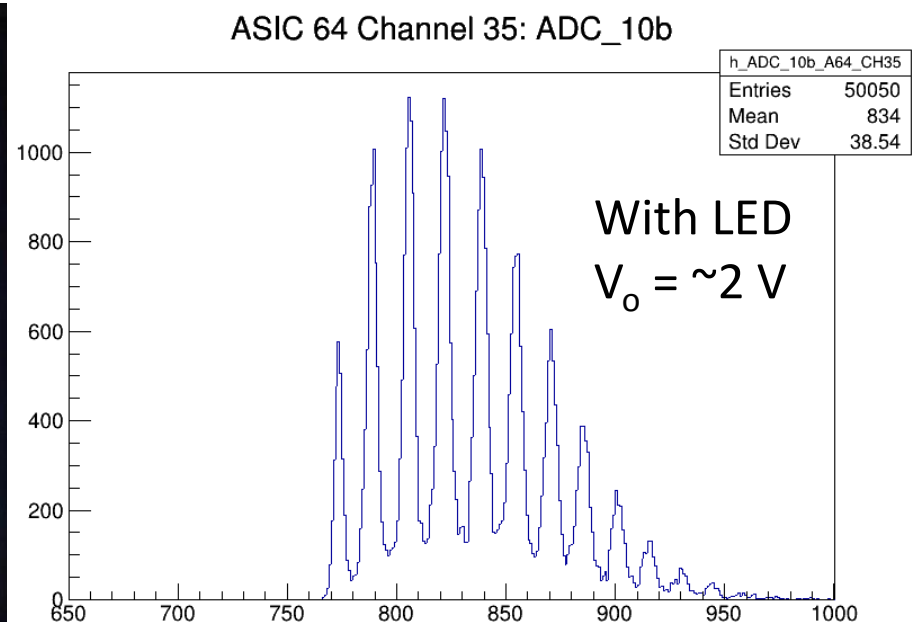
KLauS芯片在高能所测试结果 (-50℃)

闫文奇，曹国富









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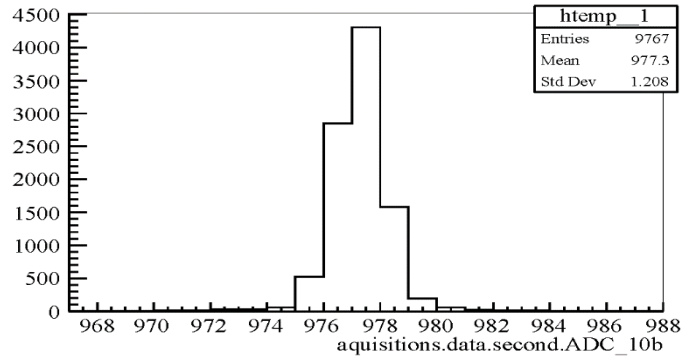

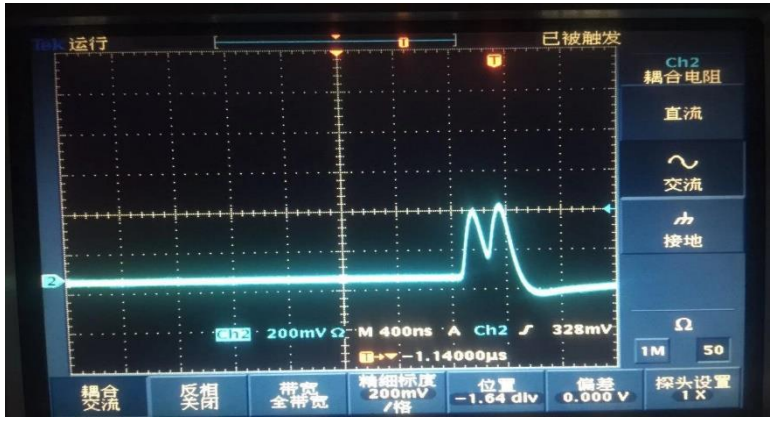

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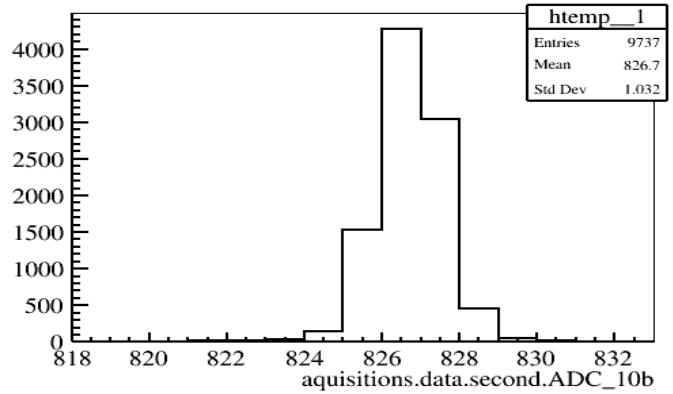

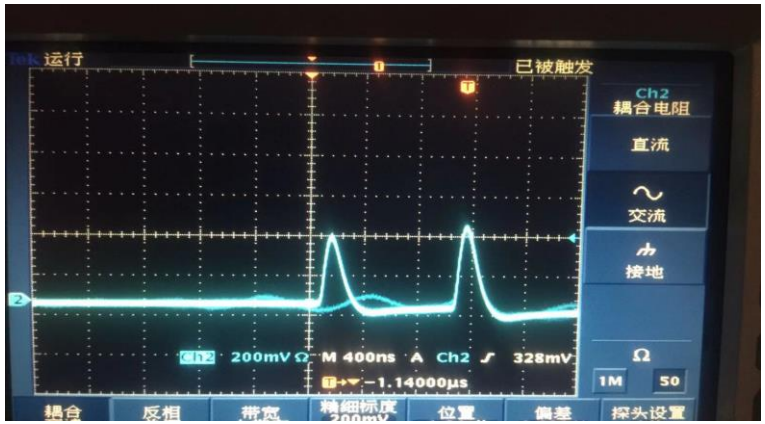

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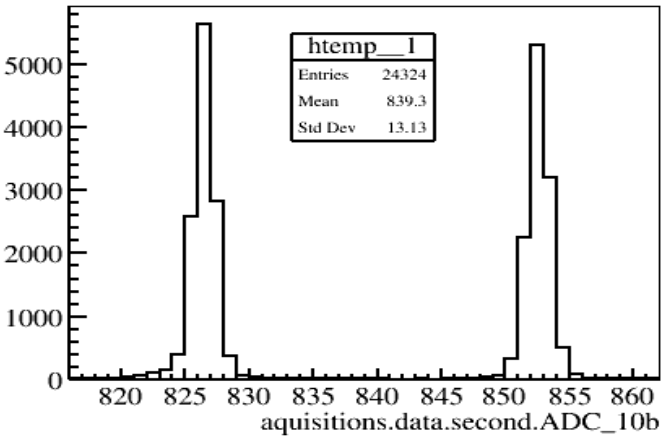
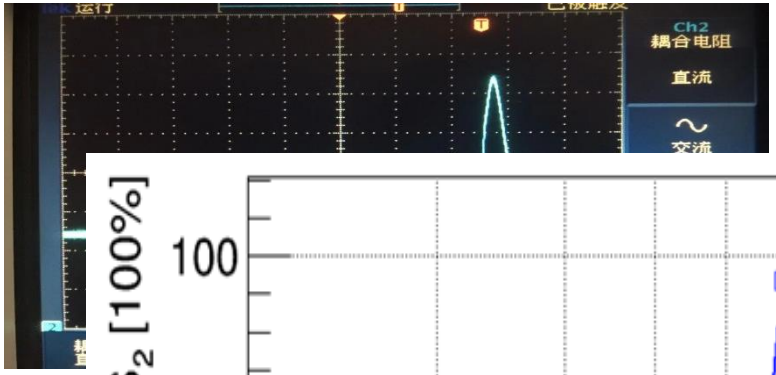
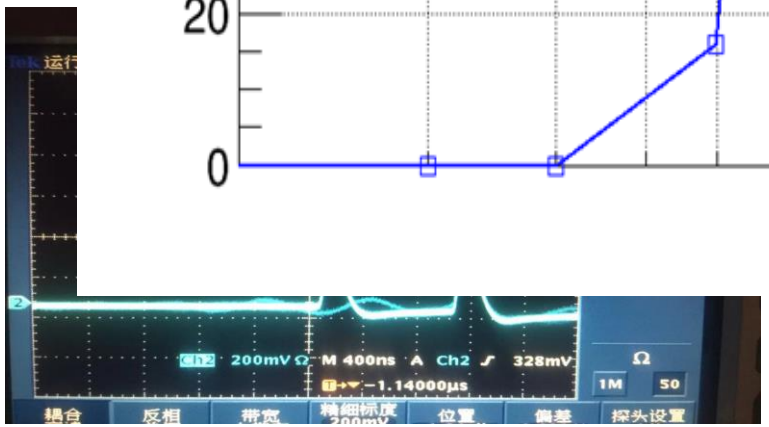


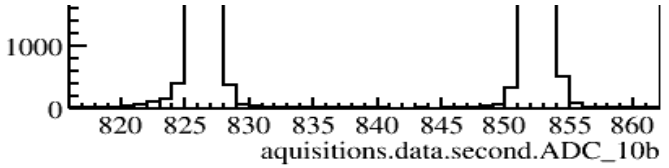
AD转换时间


Ch2
耦合电阻
直流
交流


200mV Ω
M 400ns A Ch2 328mV
-1.14000µs
1M
50
耦合
反相
带宽
精细标度
位置
偏差
探头设置


htemp 1
Entries 9767
Mean 977.3
Std Dev 1.208
4500
4000
3500

S_1/S_2 [100%]
100
80
60
40
20
0
10^3
10^4
Δt [ns]
Δt>700 ns,S1/S2=1


1000
0
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aquisitions.data.second.ADC_10b

罗凤娇，曹国富

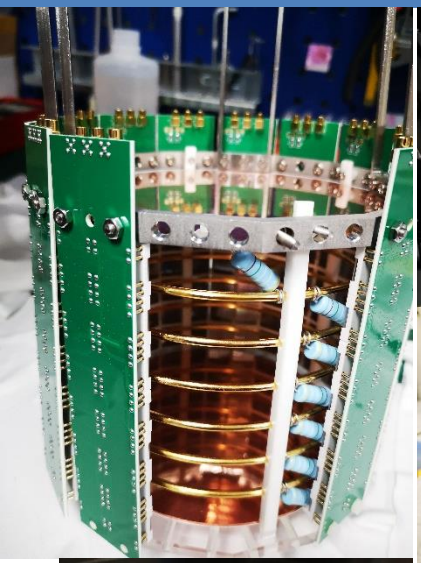
❄ 目标:

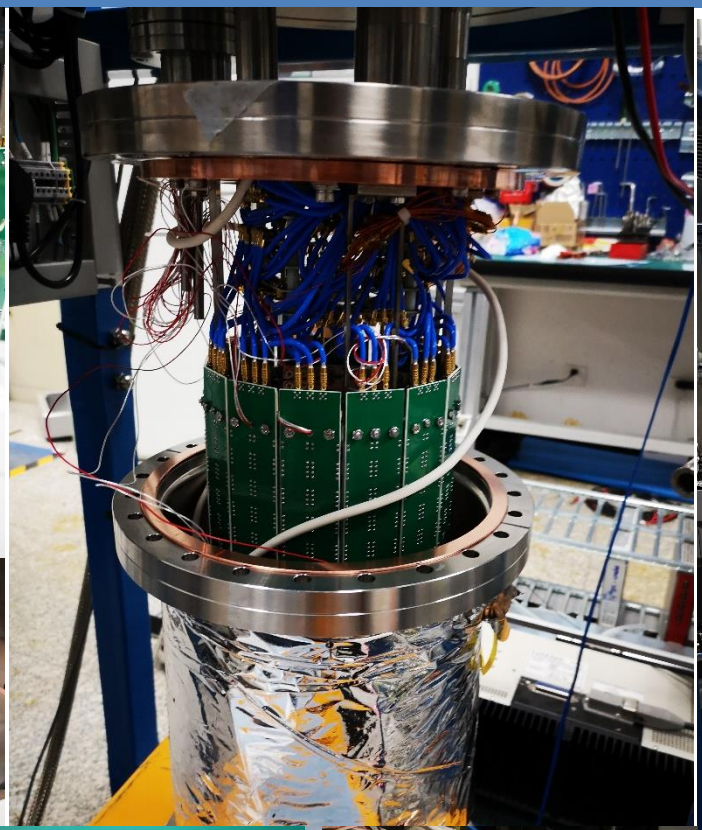
- 研究能量分辨率
- 测试电荷读出模块和读出电子学
- 测试光探测器(200片1cm^2 SiPM)性能

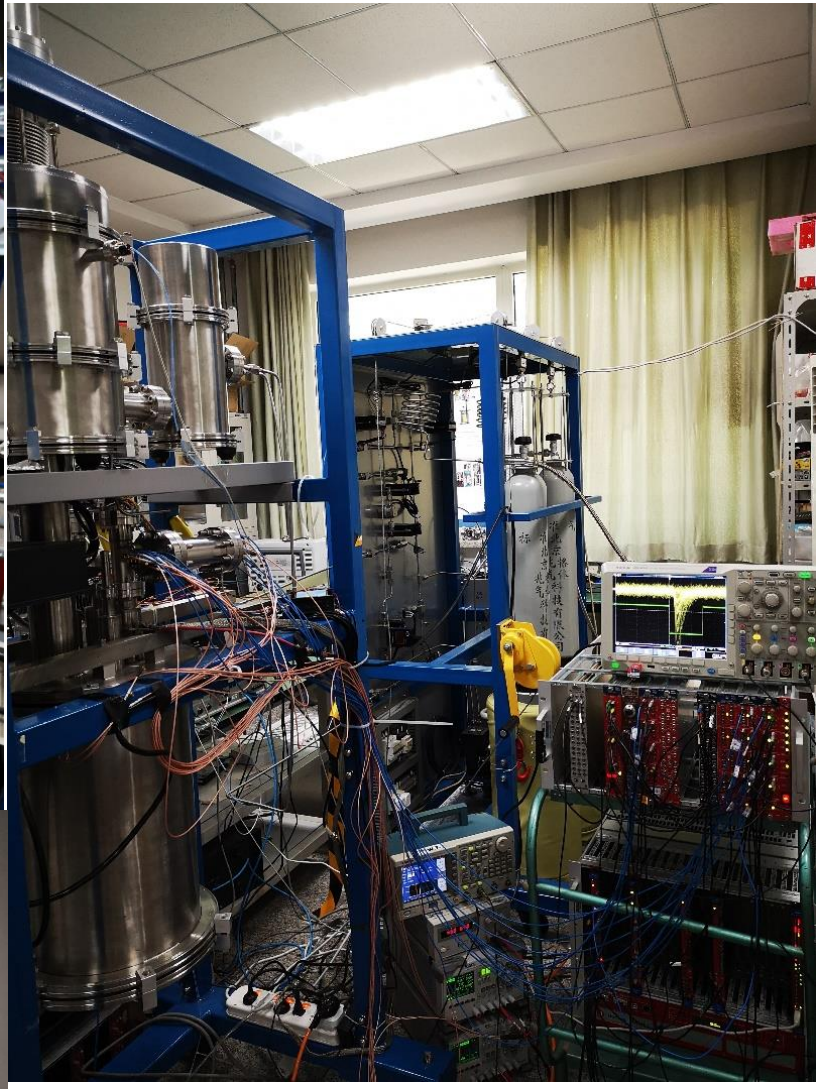
❄ 过去一年进展

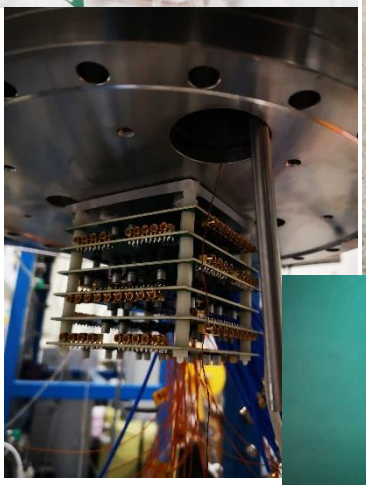
- 完成TPC清洗和安装
- 完成第一轮降温到 -120℃
- 完成SiPM探测阵列的初步测试
  - 共28路，每路读出面积 > 10 cm^2
- 发现并解决一些低温下SiPM的读出问题
- 正在进行第二轮降温

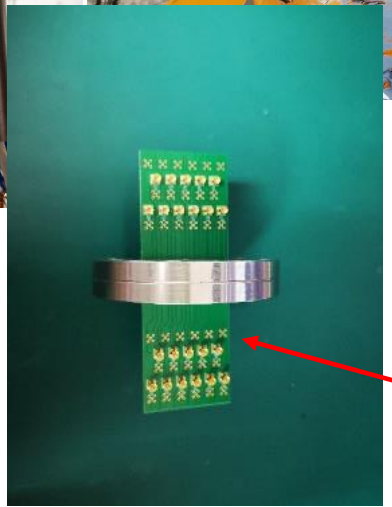
安装过程照片



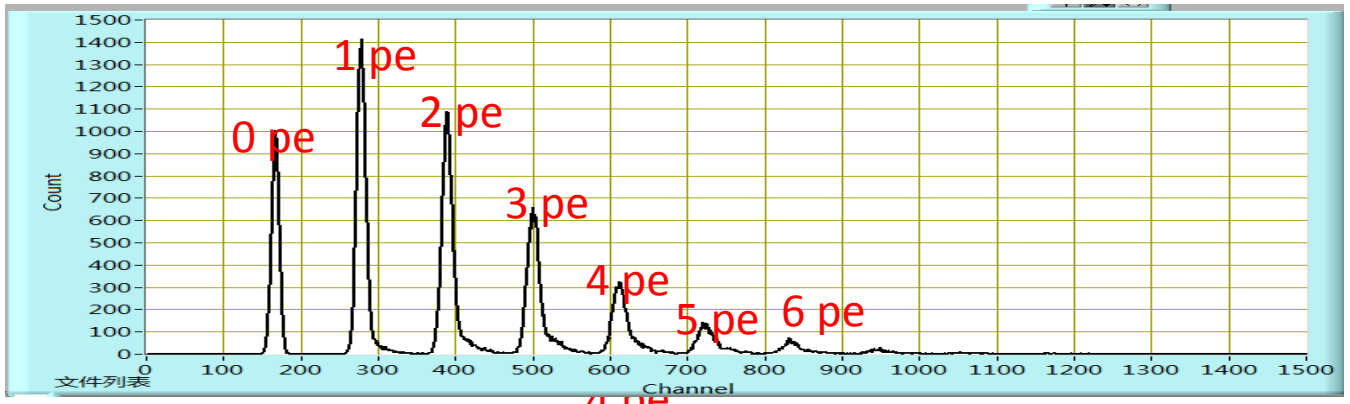








电荷谱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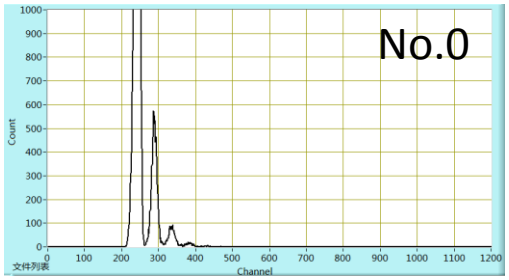
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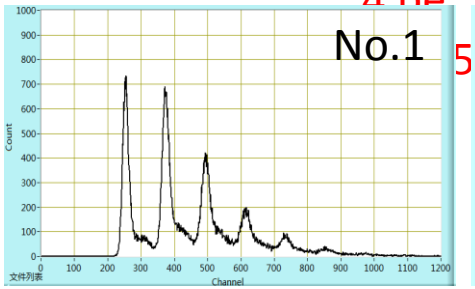
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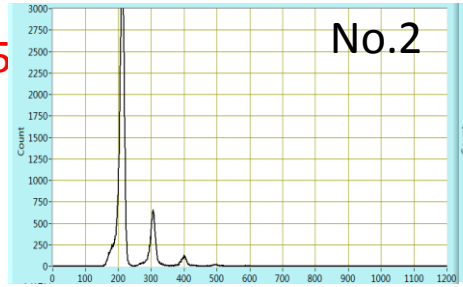
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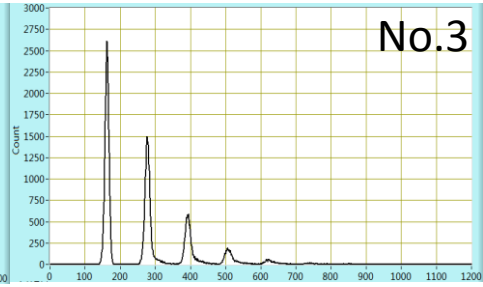
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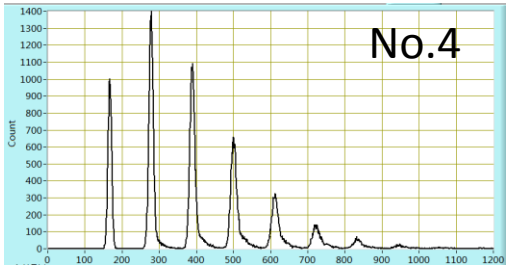
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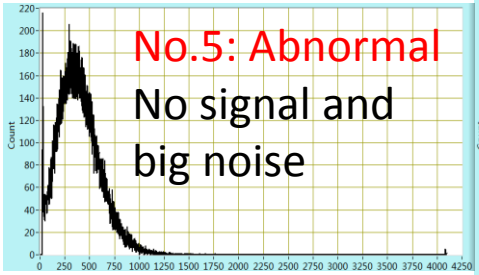
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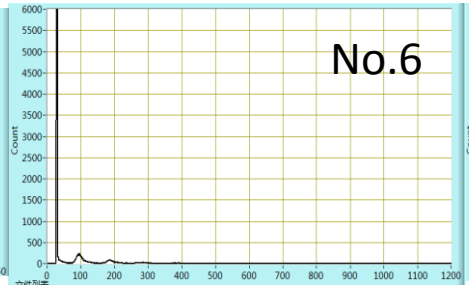
No signal and
big noise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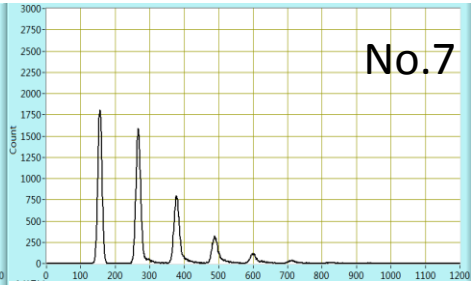
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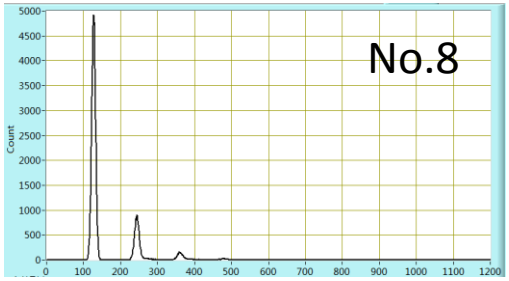
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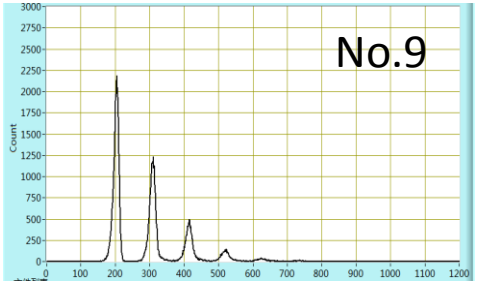
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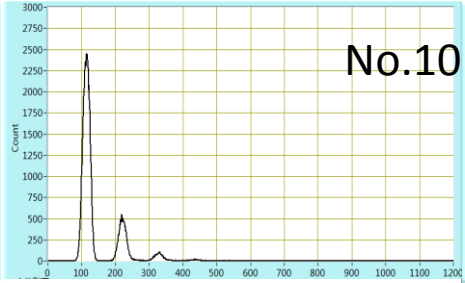
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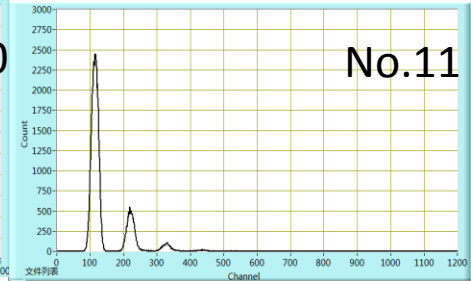
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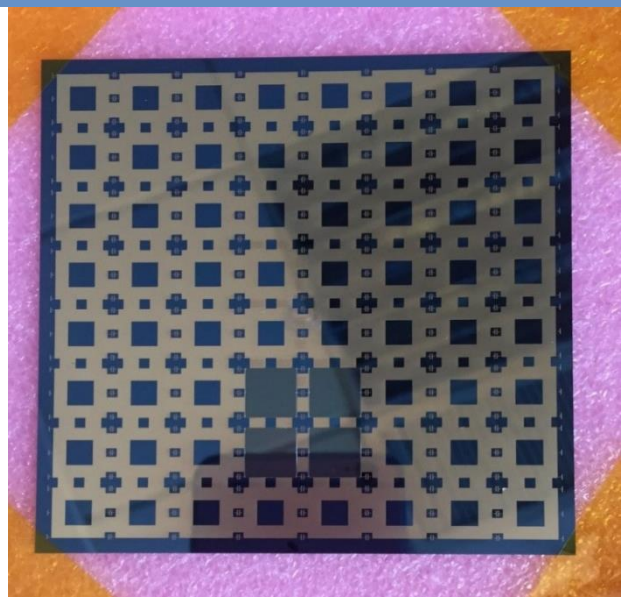
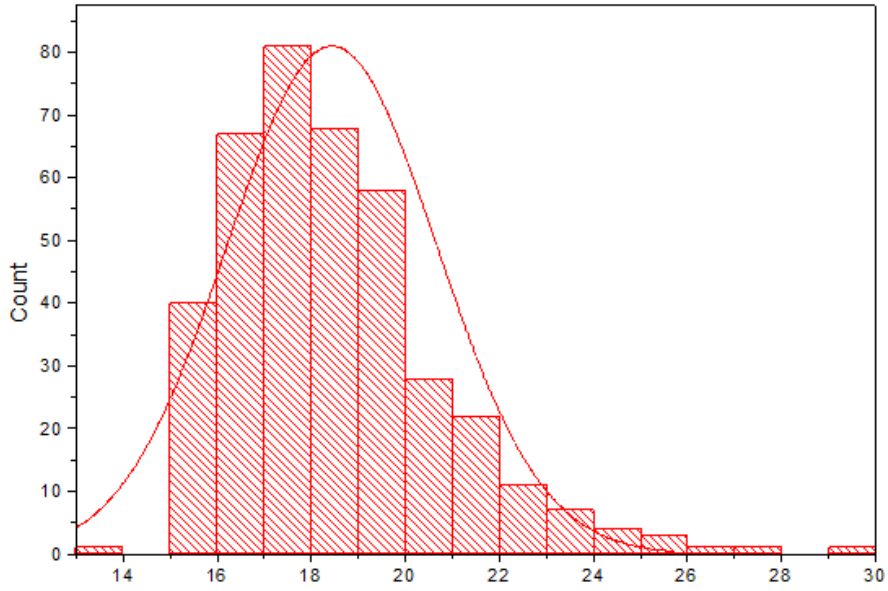
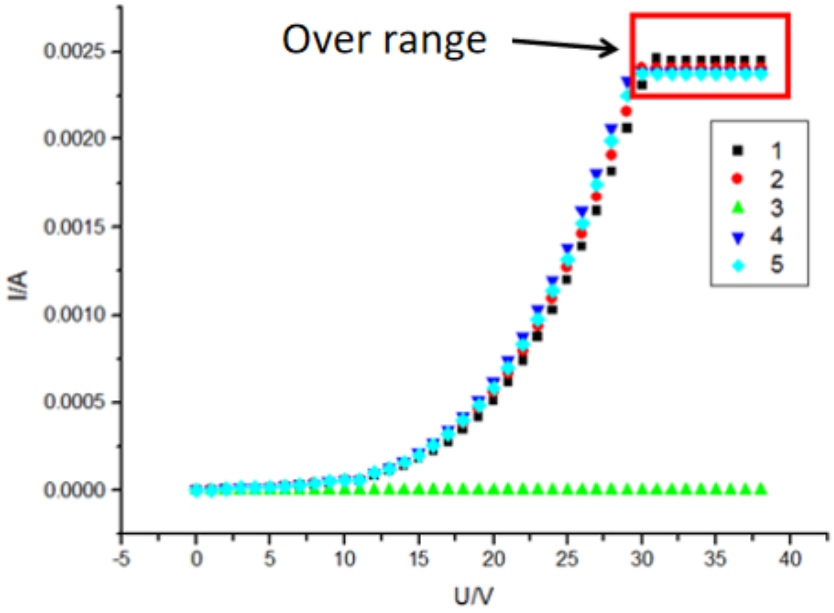
硅基转接板研发

- 极低放射性材料，与SiPM具有相近的热膨胀系数 – **理想的转接板材料！**
- 与微电子所合作
  - 微电子所：设计和制作工艺
  - 高能所：性能测试
- 17年制备了第一块10x10 cm^2 原型。
- 今年完成性能测试，发现了原型板存在的问题和原因，正在进行第二轮原型板设计与制作。







❄ 文章

① P. Lv, G.F. Cao, et al., *"Reflectance of Silicon Photomultipliers at Vacuum Ultraviolet Wavelengths"*, arXiv:1912.01841, submitted to IEEE Sensors（nEXO合作组文章，通讯作者)

② X. Fang, Y. Zhang, G.H. Gong, G.F. Cao, et al., *"Capability of detecting low energy events in JUNO Central Detector"*, arXiv:1912.01864, submitted to JINST（通讯作者）

- W. Wang, et al., *"Reflectance of Silicon Photomultipliers in Linear Alkylbenzene"*, (文章初稿基本完成）
- Y.G. Wang, et al., *"Absolute detection efficiency of PMTs"*, (撰写中)
- Z.Q. Xie, et al., *"Characterization of SiPMs at low temperature"* (准备中)
- W. Wang, et al., *"KLauS ASIC"*, (准备中)

❄ 国际会议报告

- 5th International Workshop on New Photon-Detectors, November 27-29, 2018, Tokyo, Japan.

  Contributed talk: "Photo-detector System with Large Area SiPM in nEXO"
- SiPM workshop, Oct. 1 – 5, 2019, Bari, Italy

  Contributed talk: "JUNO-TAO experiment with Large Area SiPMs"

❄ 基金

- “20英寸PMT光学响应模型研究”，面上项目，66万，负责人，2019-2022
- “大亚湾探测器精细模拟”，国家自然科学基金青年基金项目，21万，课题负责人，已结题。
- “EXO无中微子双beta衰变实验”，中美合作基金，主要参与人，2019-2023

❄ 学术活动

- 举办中国区第二届Geant4培训学校，山东大学（青岛校区）
  - 下一届计划明年8月在兰州举办
- “南山清”暑期学校，主讲探测器模拟
- 中山大学，“Workshop on Selected Frontiers”，探测器模拟
- 西安交大，讲授“Geant4基础”