—— 第五届微结构气体探测器研讨会

气体像素探测器及成像和偏振测试

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导师：冯骅 教授
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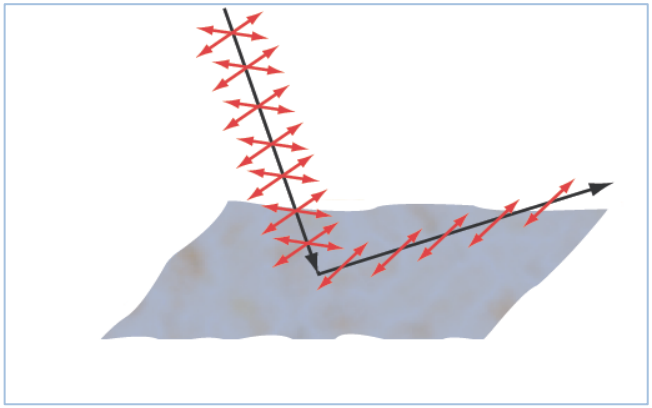
研究背景：天文X射线偏振测量

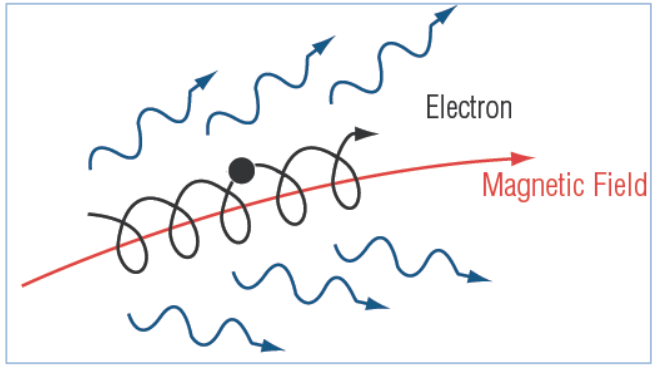
X射线天文观测手段：

时变、能谱、成像、偏振

X射线偏振测量的作用：

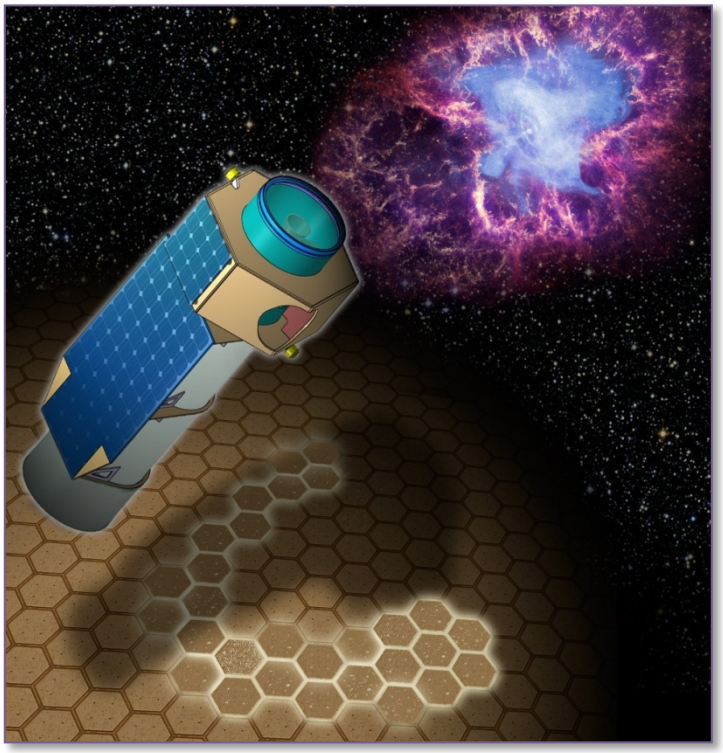
- 几何信息
  - 汤姆逊/康普顿/逆康普顿散射
  - 辐射传输中的非对称性产生偏振
- 磁场结构
  - 同步辐射产生偏振
  - 真空极化、等离子体极化
- 辐射机制



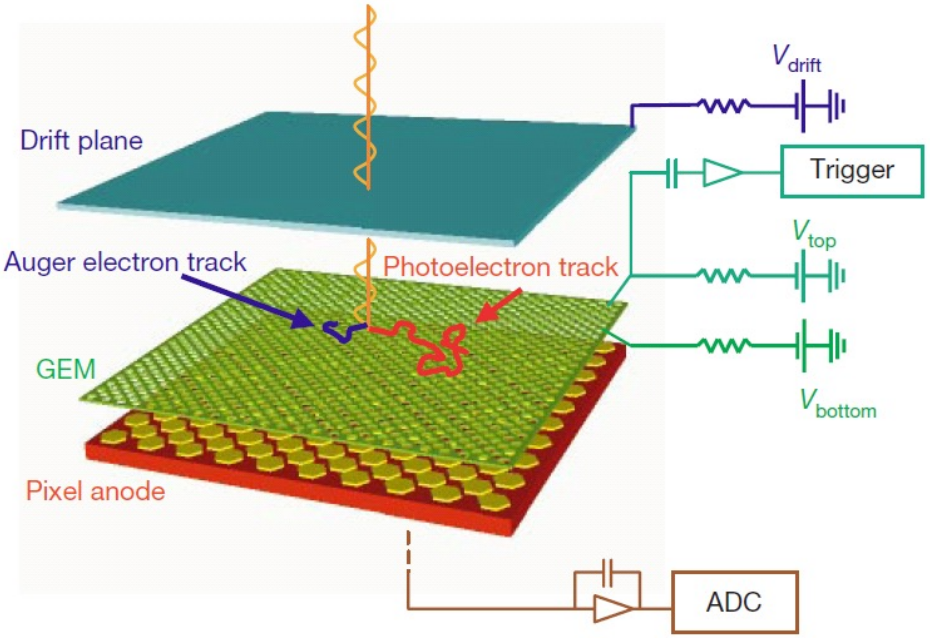


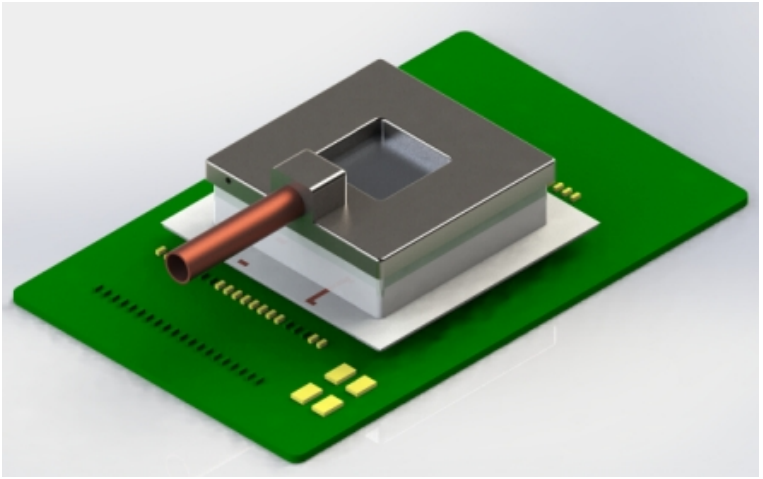
XIPE (X-ray Imaging Polarimetry Explorer)

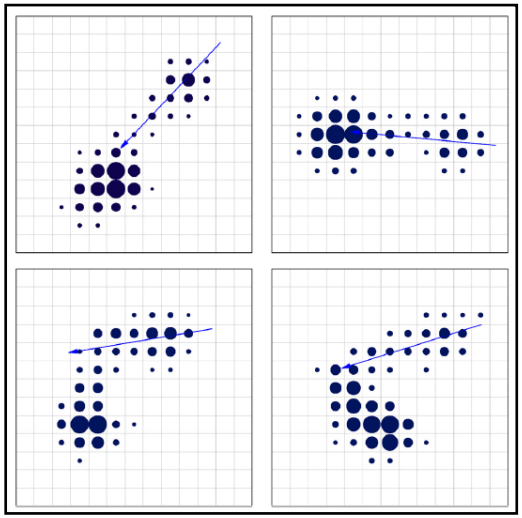
- 2015年入选欧空局中等尺度空间项目提案(M4)
- 3年Phase A研究，确定立项，2025年发射
- 中方贡献
  - 科学：8个研究机构
  - 仪器：焦平面探测器的优化设计及标定，滤镜设计

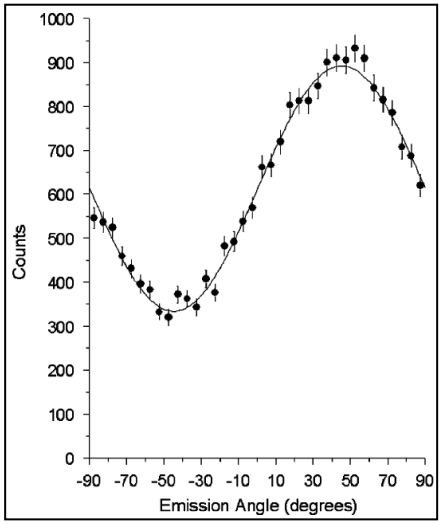


气体像素探测器(GPD)







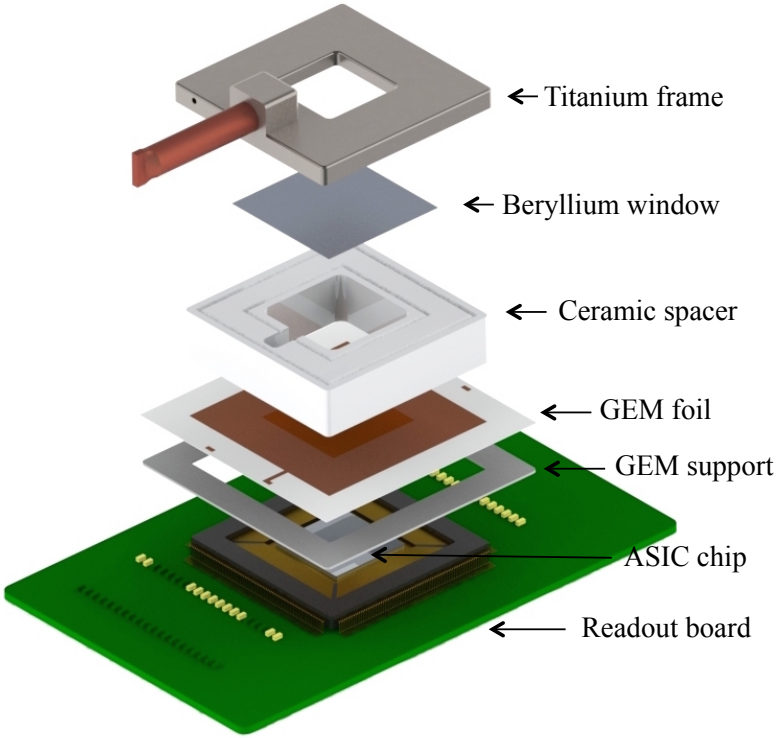


偏振信息：

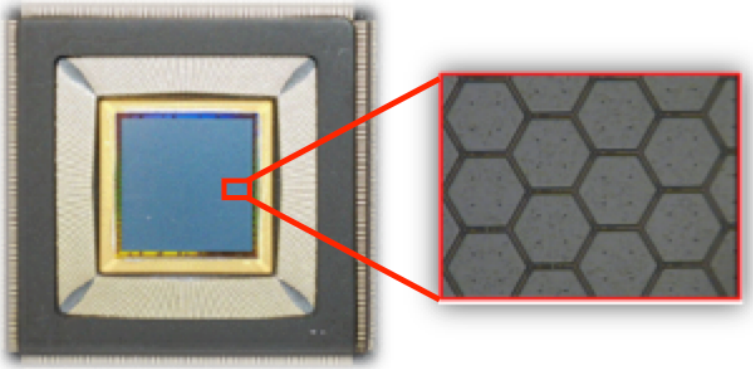
$$Ang. = \varphi_0$$

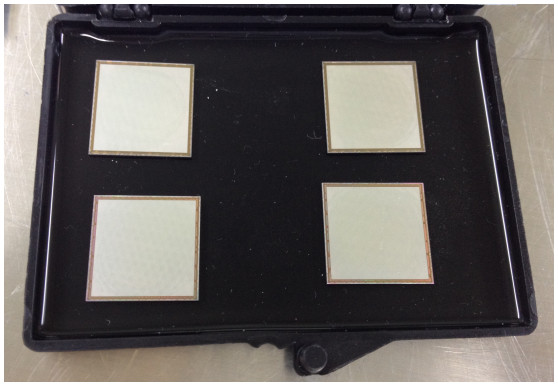
$$Pol. = \frac{N_{\max} - N_{\min}}{N_{\max} + N_{\min}} \frac{1}{\mu}$$

Gas Pixel Detector (GPD)



入射窗	Be, 100μm
漂移区	1 cm
GEM	LCP-GEM, SciEnergy T100 – P80 – D40 T50 – P50 – D30
ASIC芯片	CMOS VLSI Area：15mm×15mm Pixels：300 × 352 Noise：~50 e- rms Linear range：FS=5fC Internal/external trigger

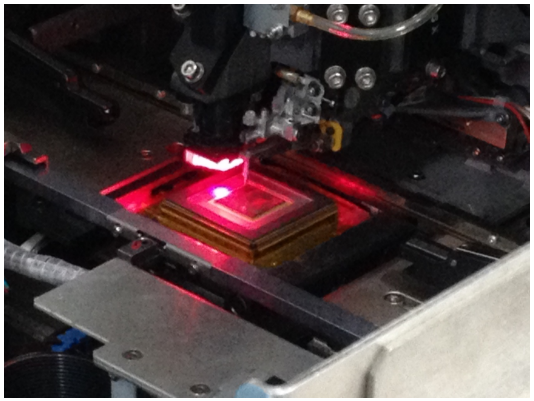




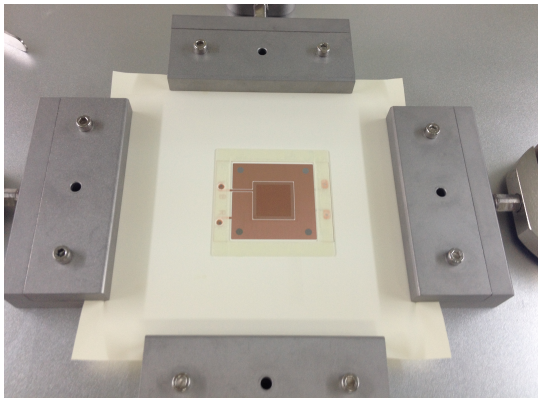
Bellazzini et al.

探测器装配

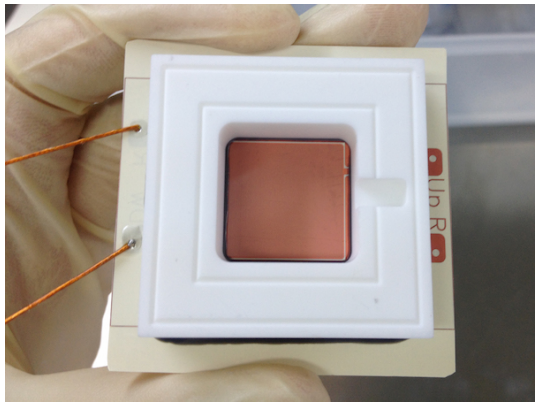
芯片封装



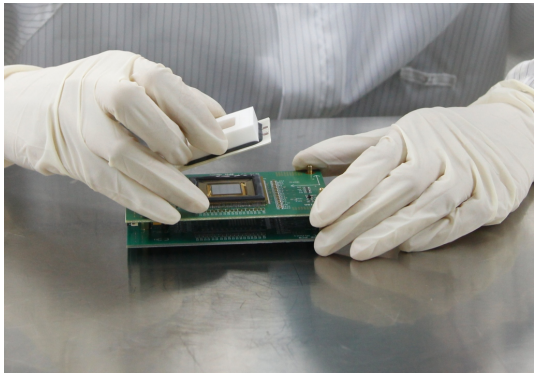
GEM绷膜加框



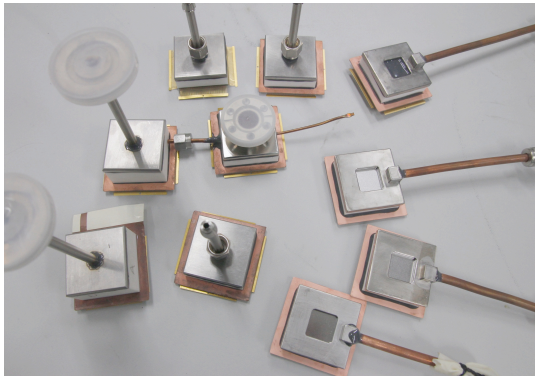
陶瓷腔体和GEM



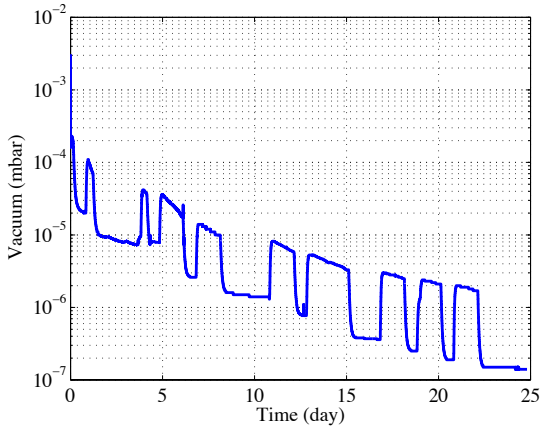
粘合腔体



测试铍窗和腔室密封

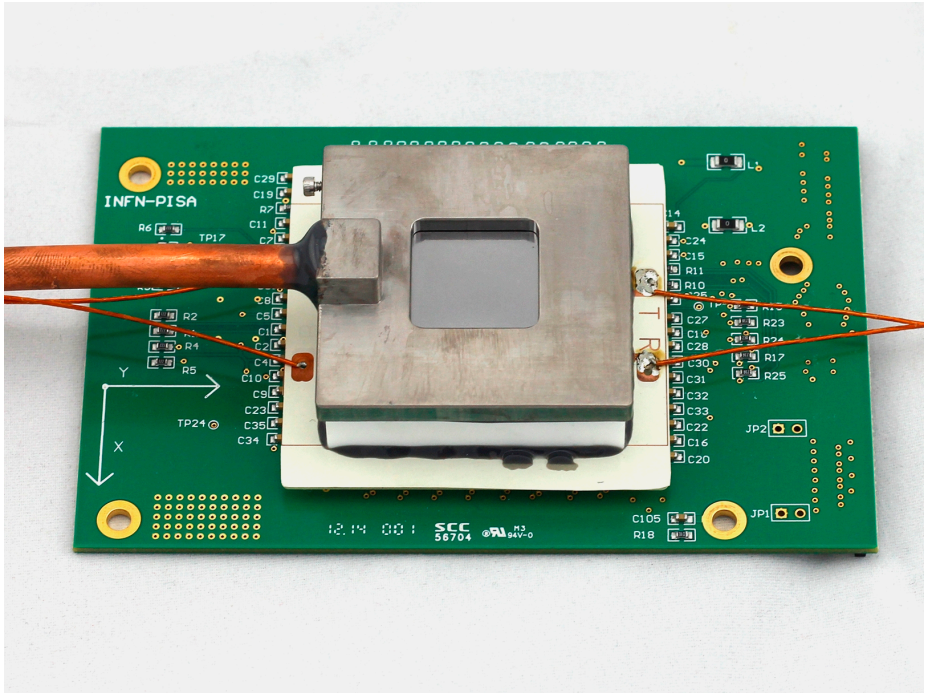


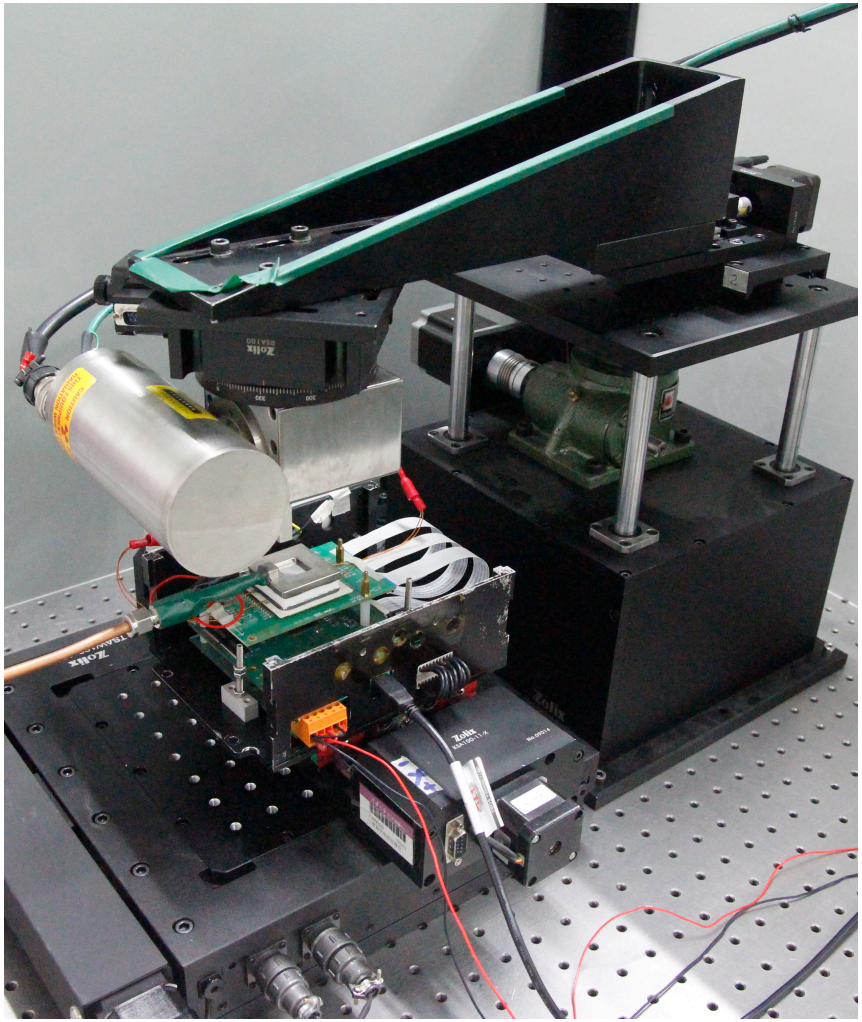
加热除气



已实现长寿命闭气型气体探测器的装配

GPD性能测试及标定





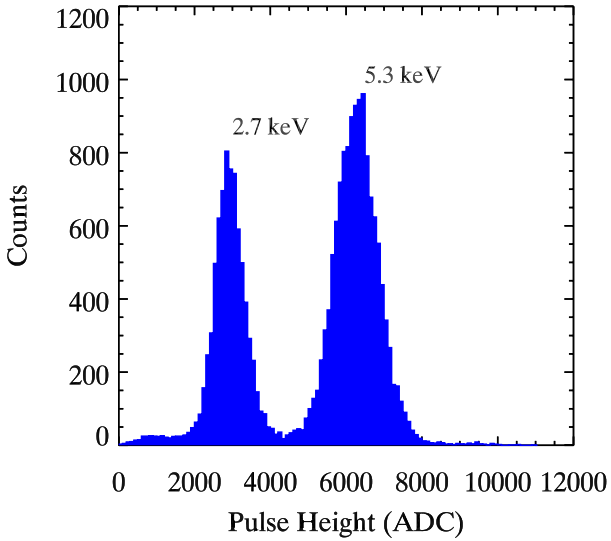
工作气体:

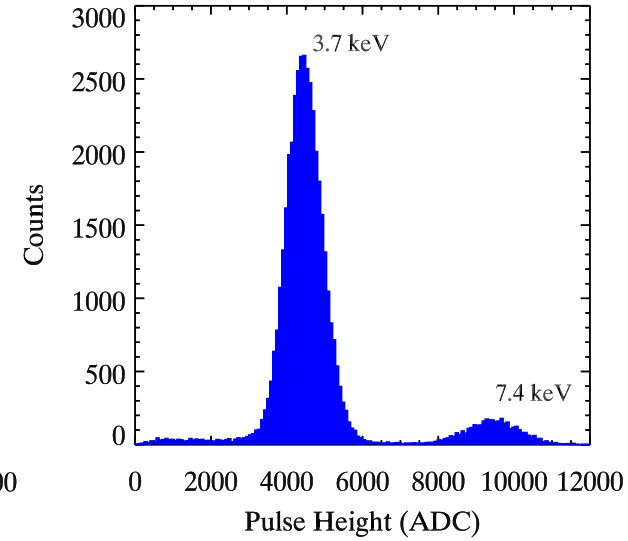
Ne:CO2=7:3@1.0atm

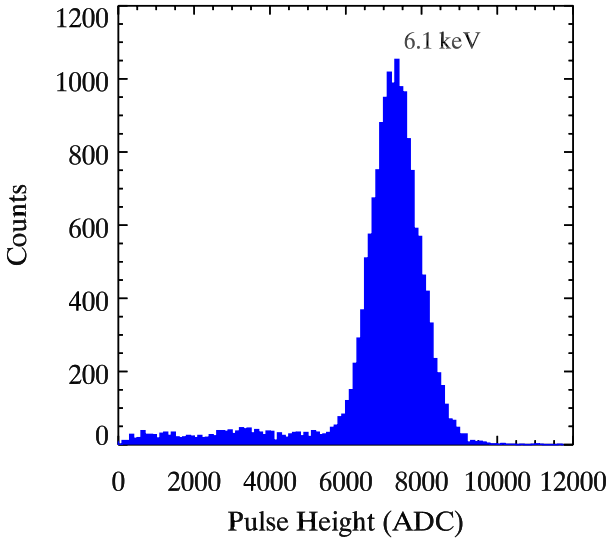
Pure DME @0.8atm

He:DME=2:8@1.0atm

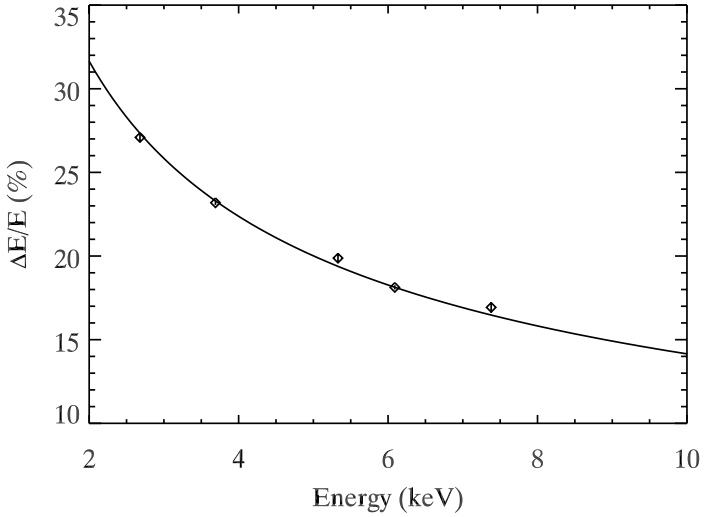
• 能量响应



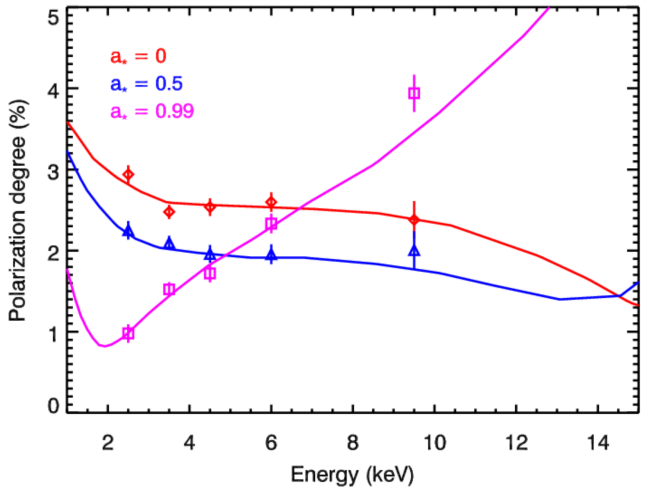




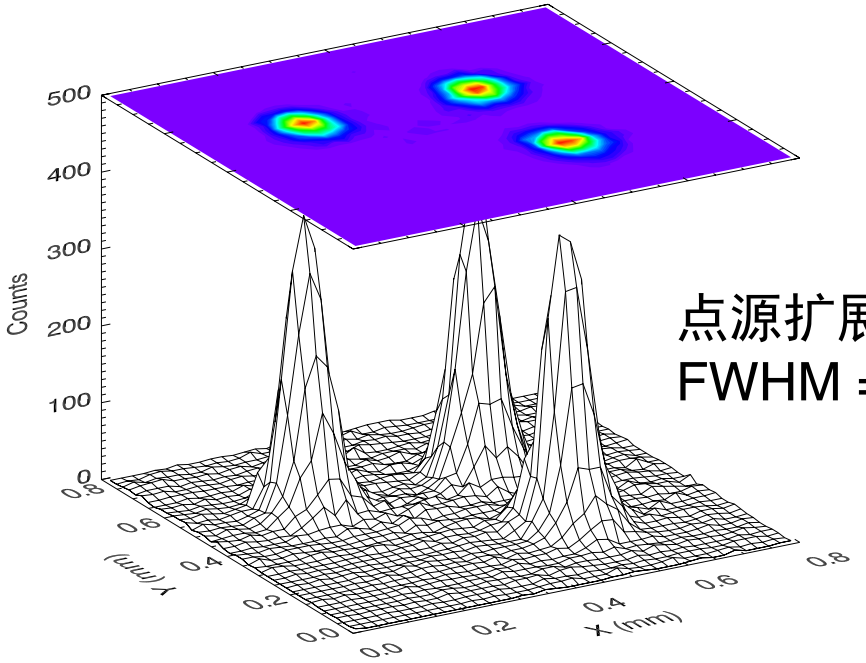
能量分辨率
FWHM = 18% @6.1keV



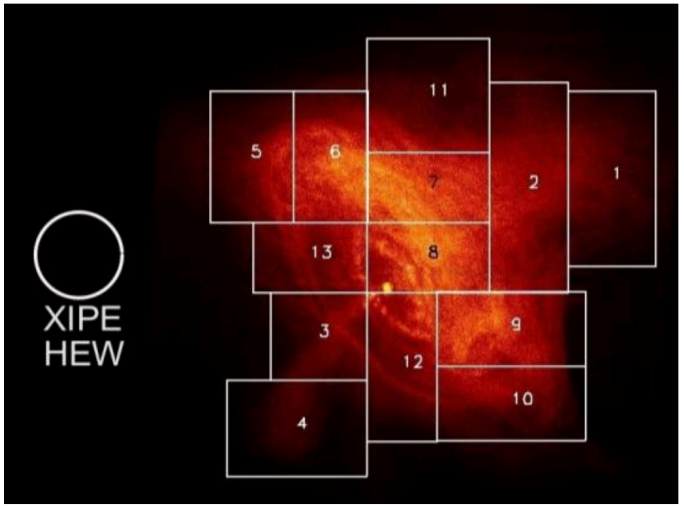
获取X射线天体的偏振谱，
限制模型



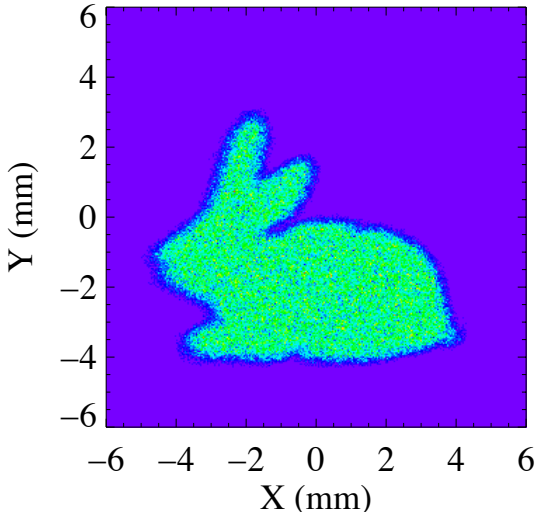
• 二维成像

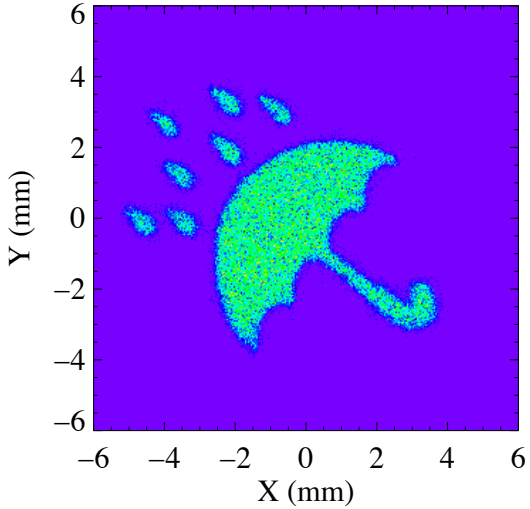


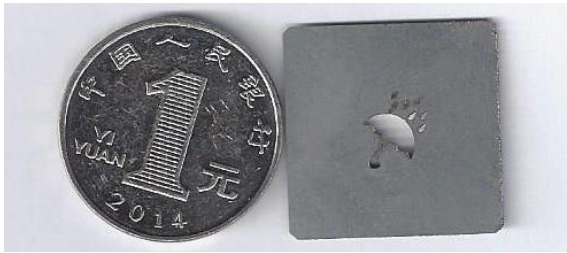
点源扩展
FWHM = 80 μm



未来装载在X射线光学系统的焦平面上，可实现对扩展源不同位置的偏振测量

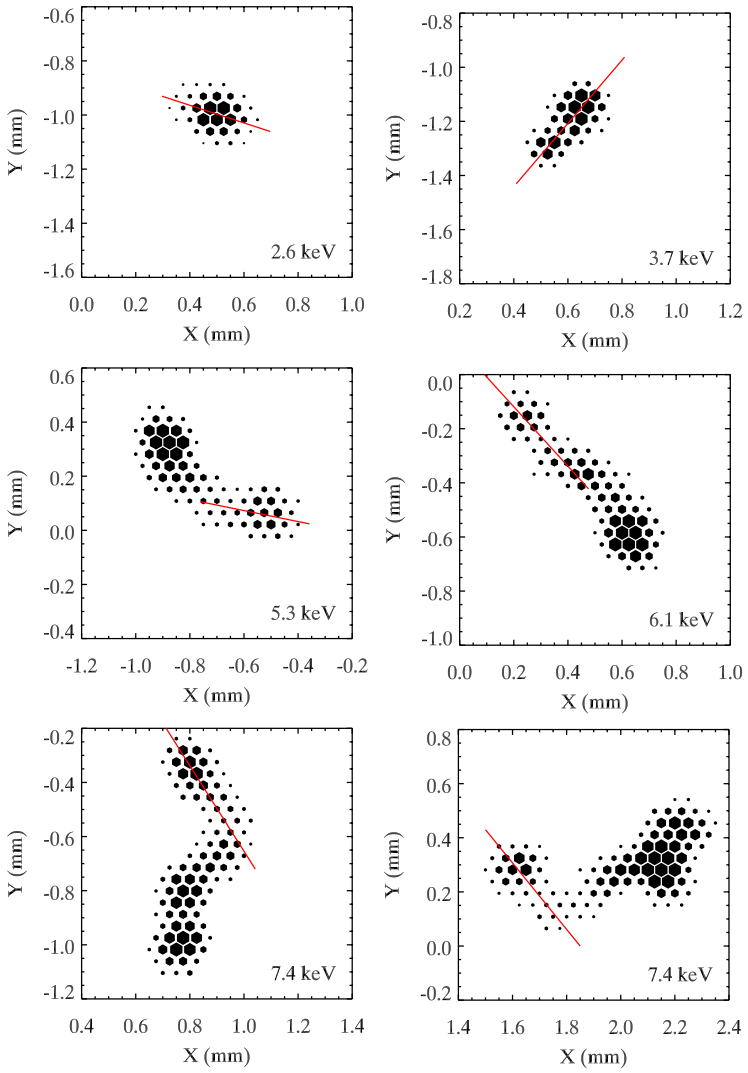




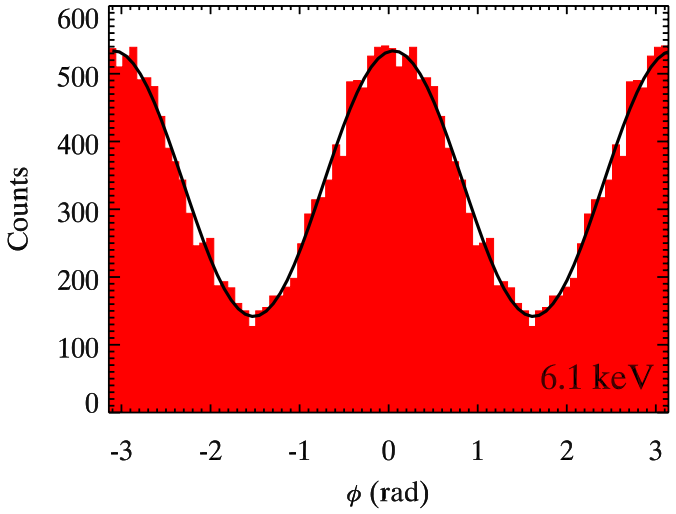


• 偏振测量

二维光电子径迹



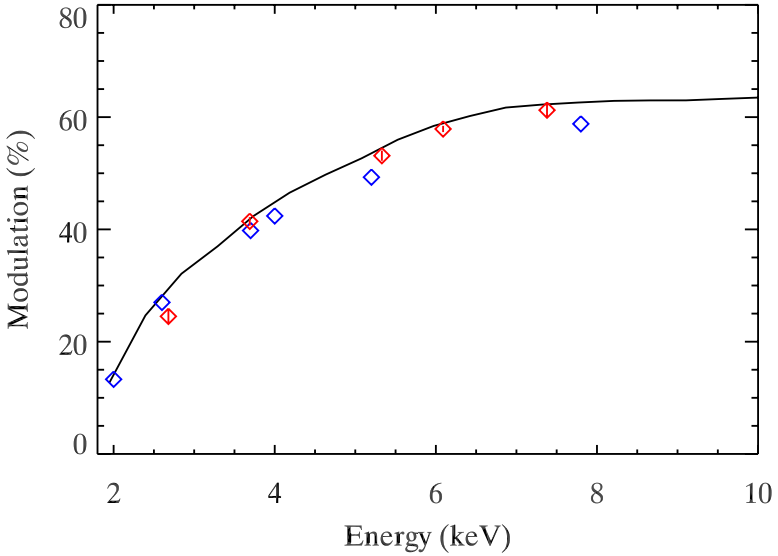
调制曲线



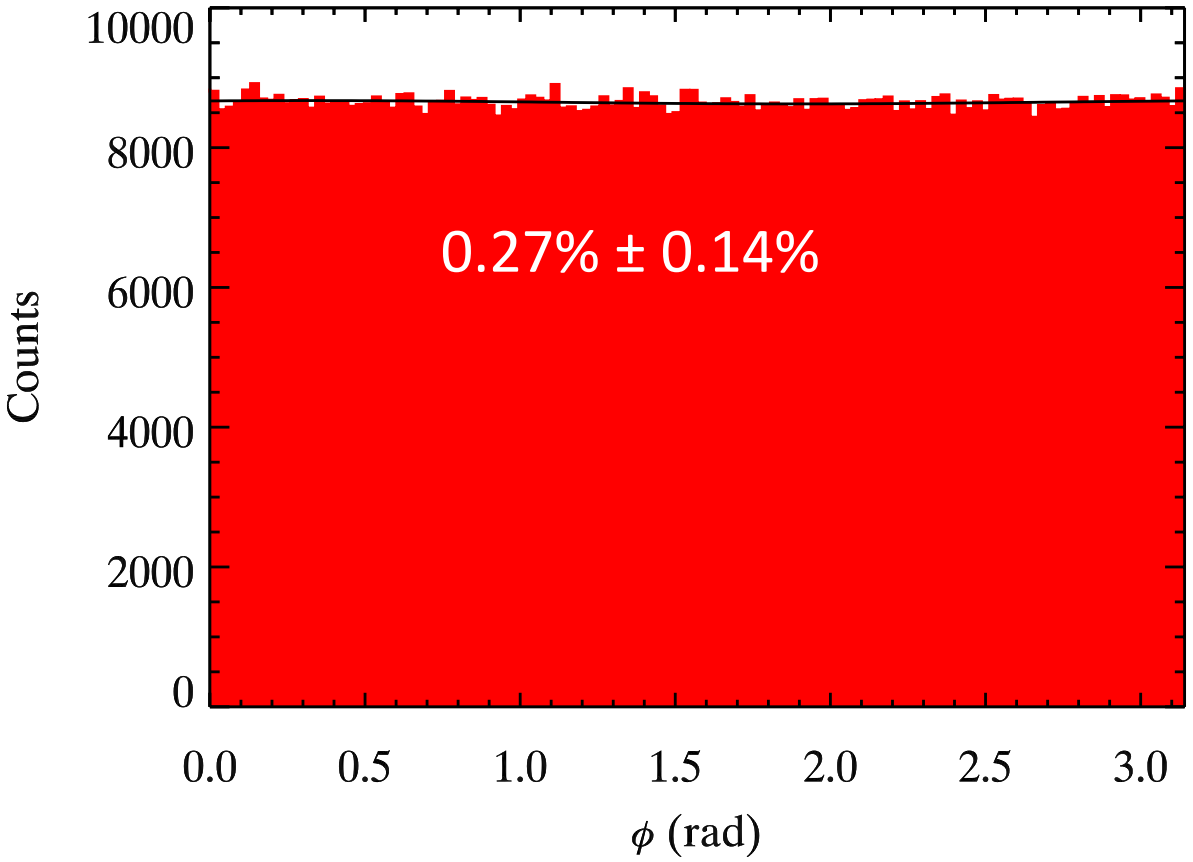
$$Ang. = \varphi_0$$

$$Pol. = \frac{N_{\max} - N_{\min}}{N_{\max} + N_{\min}} \frac{1}{\mu}$$

调制因子

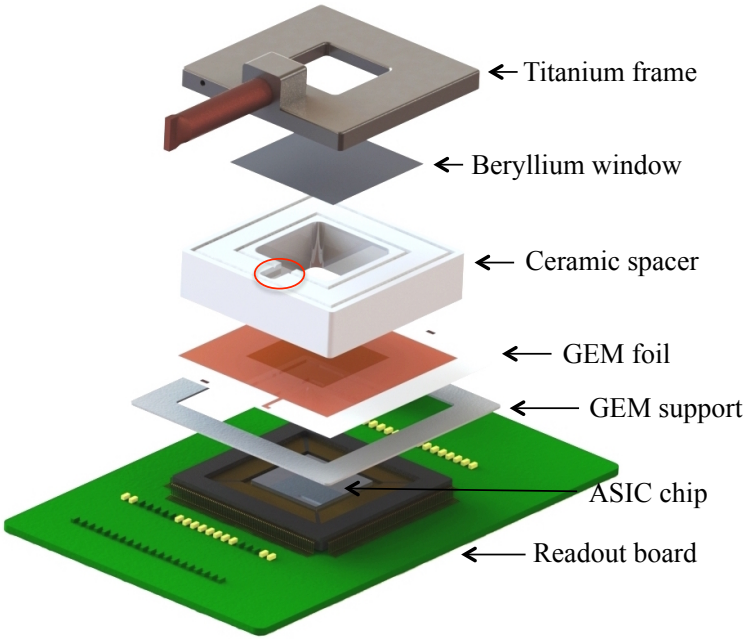


- 系统误差

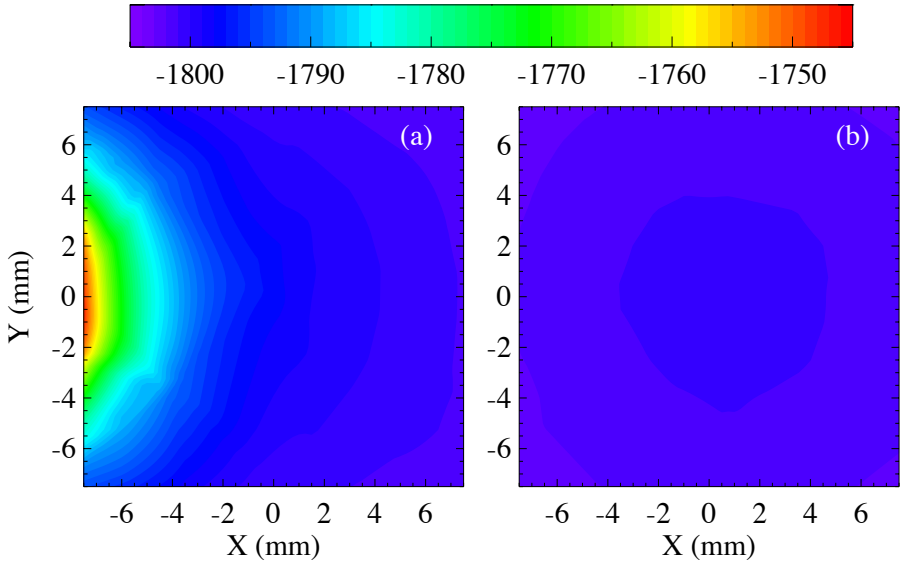


控制系统误差是偏振测量的最重要问题，NASA的偏振仪系统误差在仪器旋转的情况下才能到1%

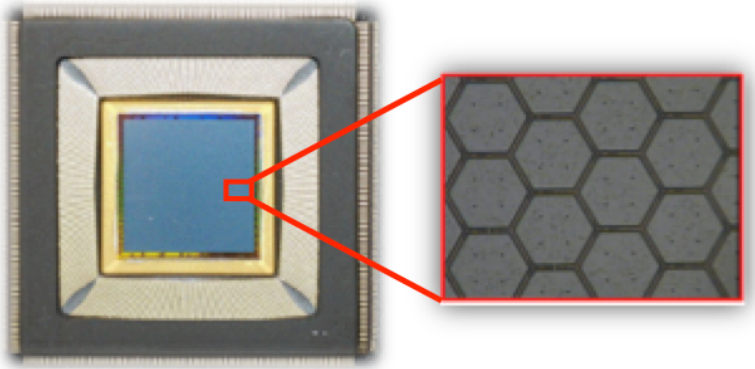
• 系统误差

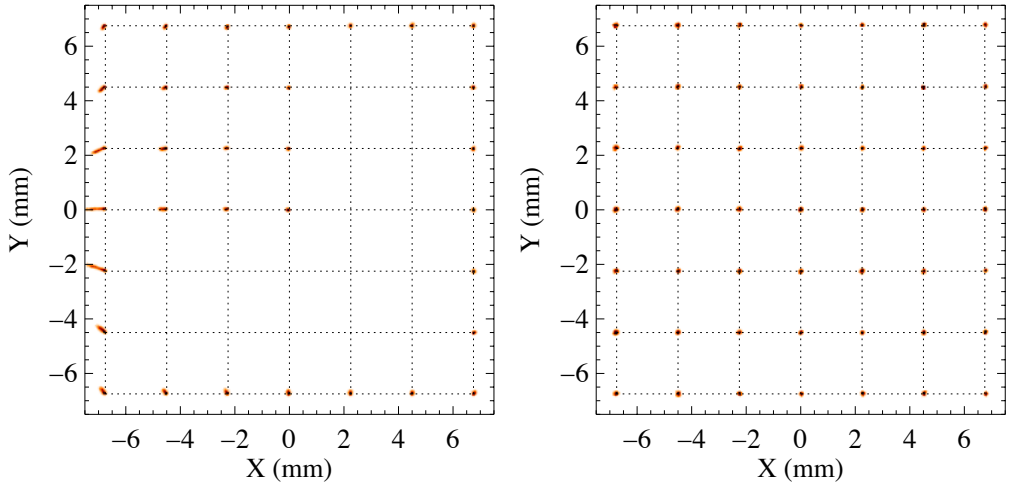


2. 漂移电场一致性

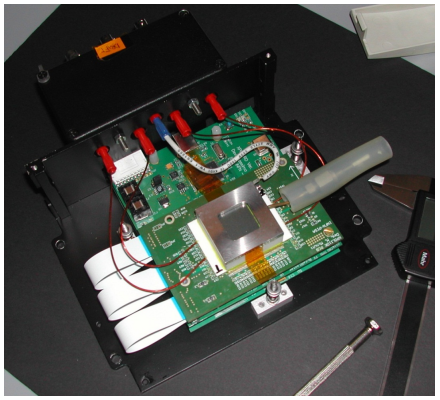


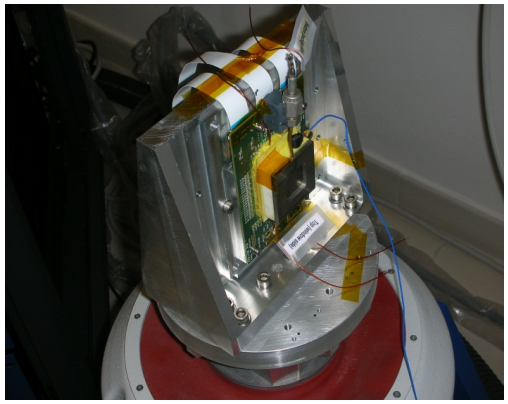
1. 二维像素读出，优于TPC

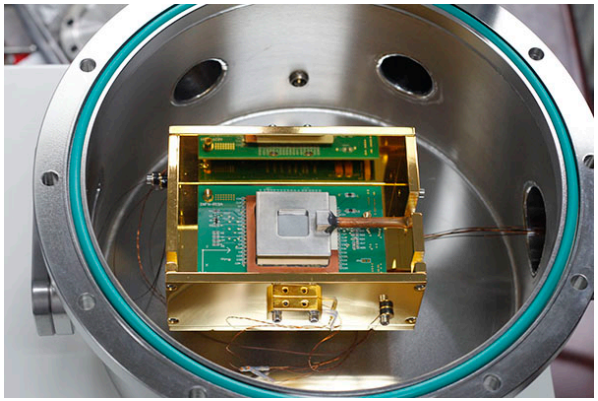


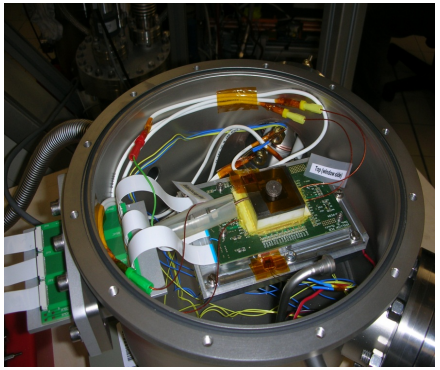


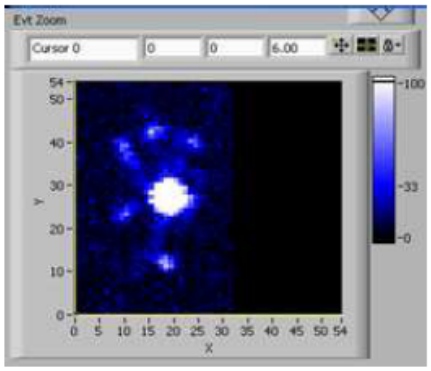
• 空间环境测试









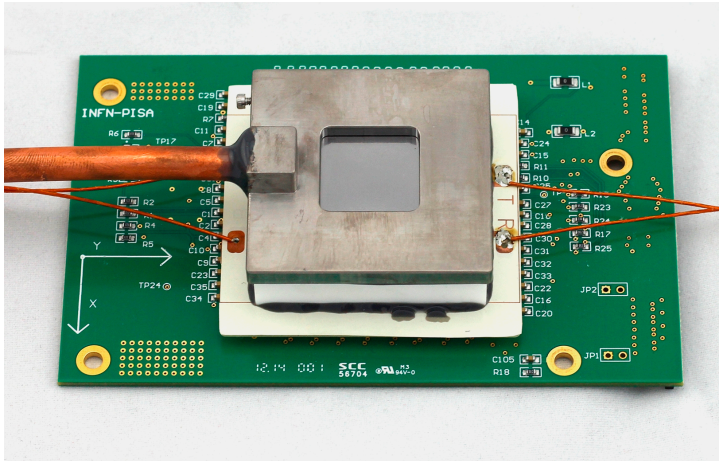


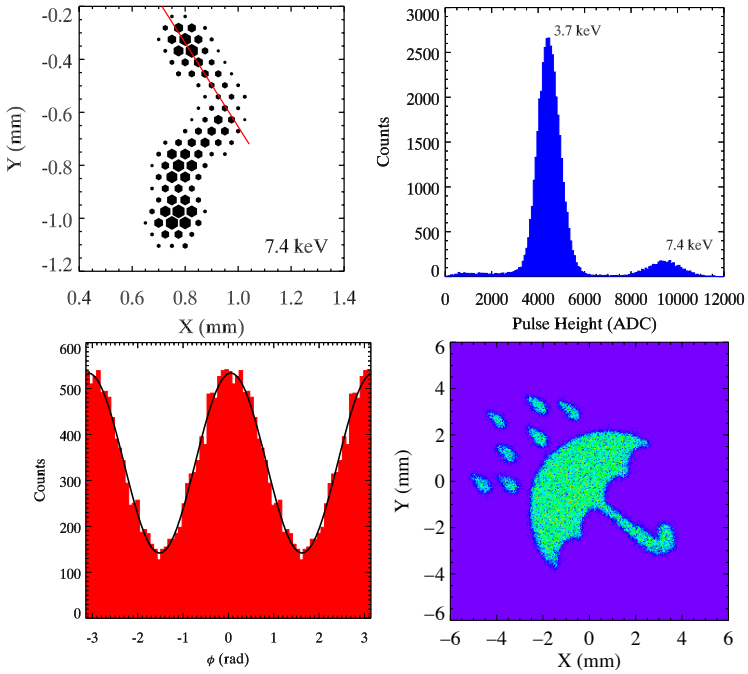
- 上一版本通过了初步摸底试验
  - 冲击
  - 振动
  - 热真空循环
  - 重离子轰击
  - 技术成熟度 TRL = 6
- 将针对新探测器进行进一步试验

总结

气体像素探测器(GPD)：

- 有效读出面积15mm×15mm
- 探测能区：2-30keV X-ray
- 位置分辨率 FWHM ~80μm
- 能量分辨率 18% @6.1keV
- 偏振调制因子 0.58 @6.1keV
- 应用：未来空间X射线偏振探测项目XIPE、XTP、LAMP





谢谢！

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hfeng@tsinghua.edu.cn