



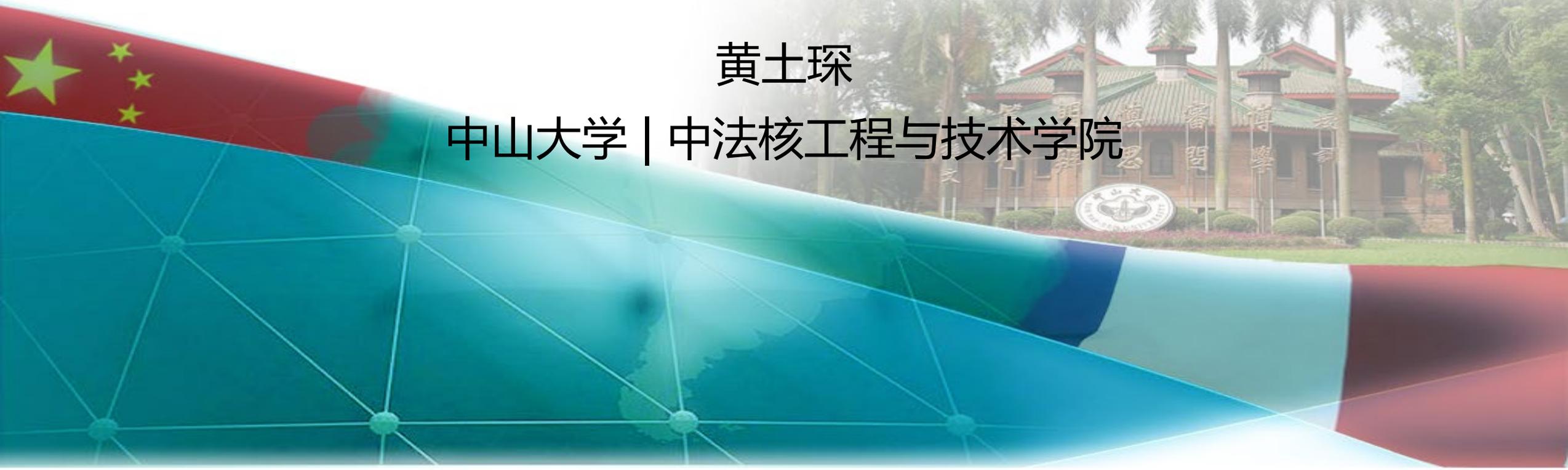
中山大學中法核工程与技术学院

Institut franco-chinois de l'énergie nucléaire université Sun Yat-sen

# SiPM阵列替代PMT用于闪烁体读出研究

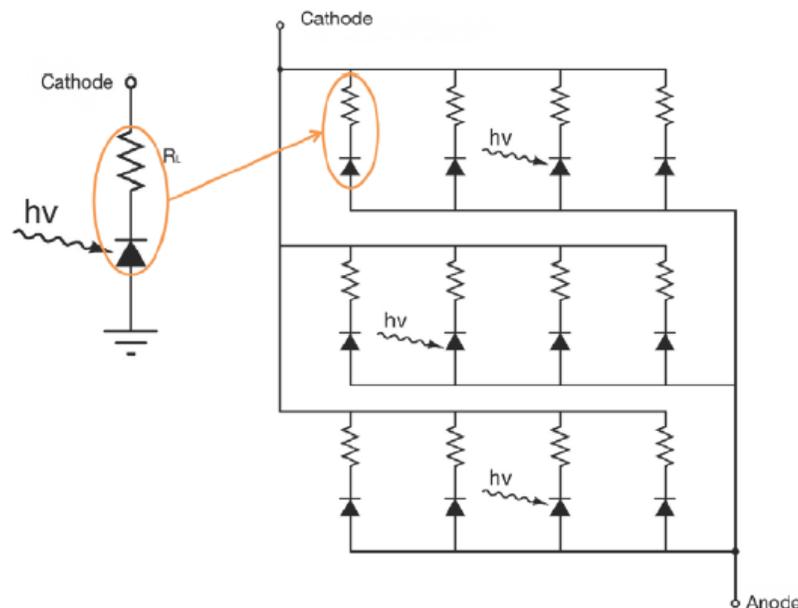
黄土琛

中山大学 | 中法核工程与技术学院





# PMT vs SiPM



	PIN	APD	PMT	SiPM
增益	1	$\sim 10^2$	$\sim 10^6$	$\sim 10^6$
工作电压	低	中等	高	低
读出电路	复杂	复杂	简单	简单
体积	小	小	大	小
机械强度	高	中等	低	高
磁场敏感	否	否	是	否
颤噪声	是	是	否	否
直接伽马反应	是	否	否	否
温度敏感性	低	高	低	低
成本	低	低	高	低

## SiPM缺点:

暗噪声高、电容大、动态范围小、单片面积小

应用: 能谱测量、波形甄别

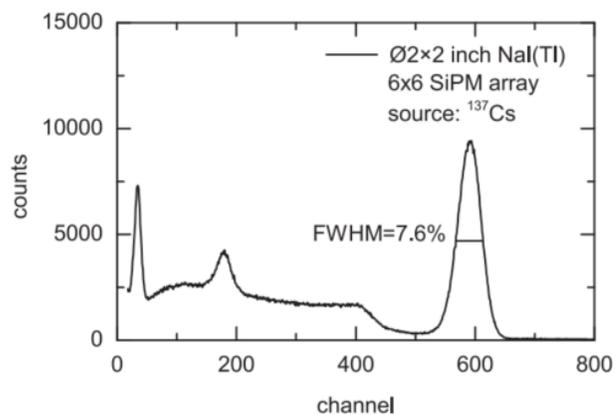
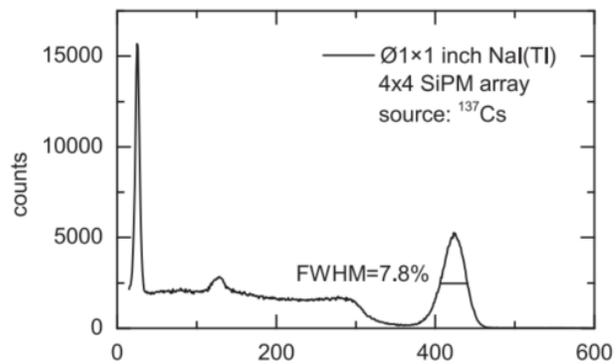
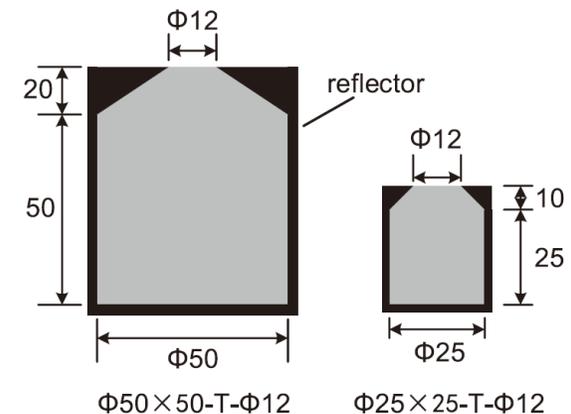
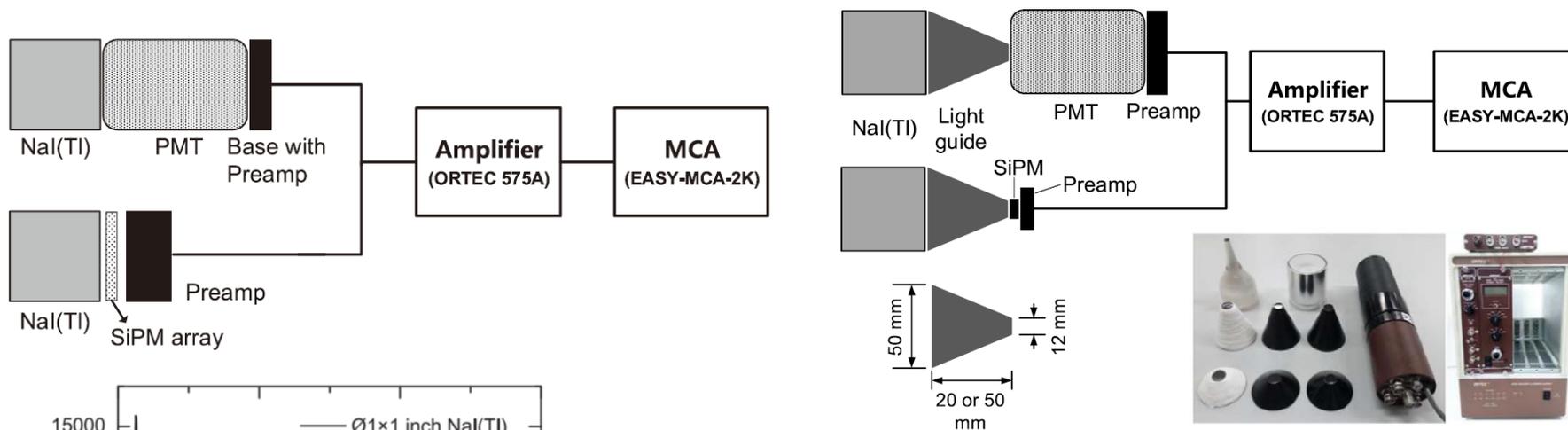
兼容: 单路输出, 兼容现有电子学

指标: 能量分辨率、线性度、PSD、成本



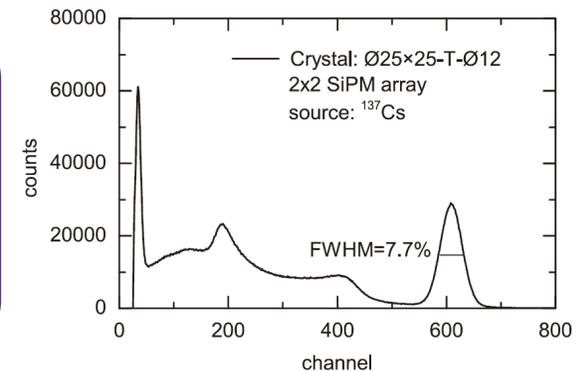
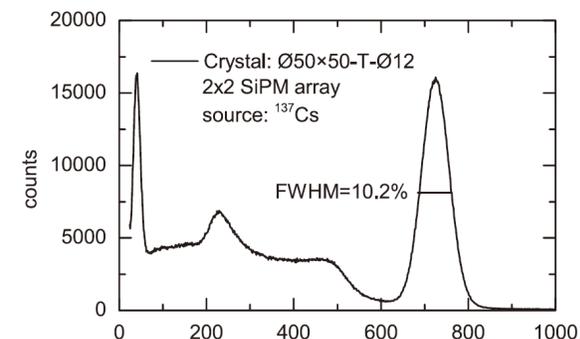
# SiPM + NaI(Tl)

NIMA 851 (2017) 118-124



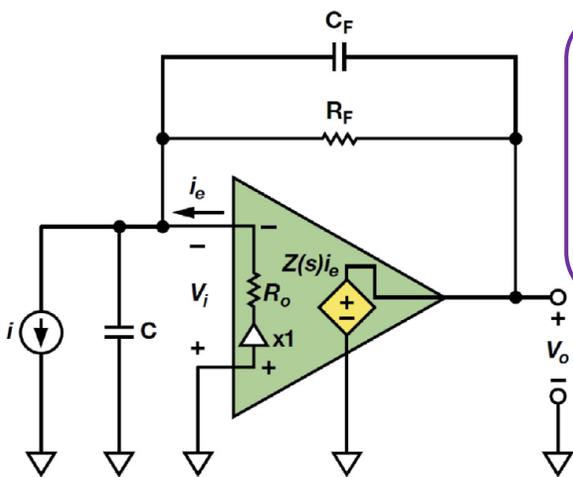
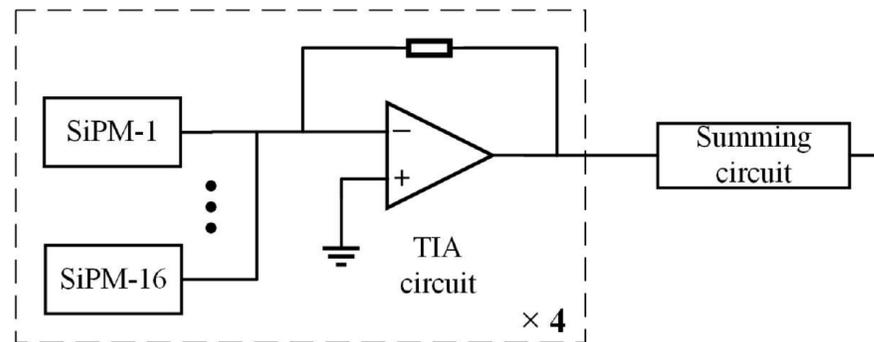
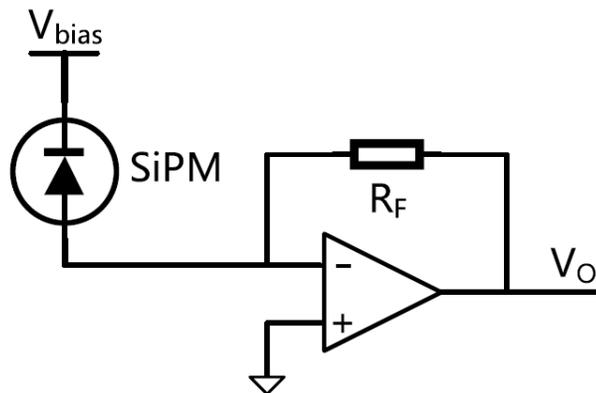
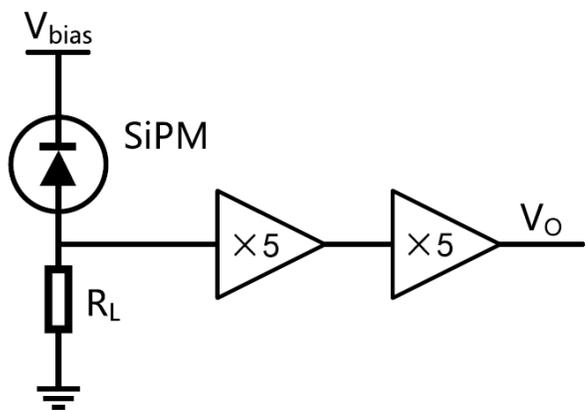
scintillator	light guide	photodetector	energy resolution (%) at peaks (keV)	
			511	661.6
Ø2 × 2 in.	None	PMT	8.2 ± 0.3	7.3 ± 0.2
Ø2 × 2 inch	L=20 mm PTFE wrapping	PMT	11.8 ± 0.6	10.5 ± 0.6
Ø2 × 2 inch	L=20 mm PTFE wrapping	2×2 SiPM array (12 × 12 mm <sup>2</sup> )	13.2 ± 0.7	11.7 ± 0.7

- 对于中等能量分辨率闪烁体, SiPM读出和PMT读出性能相当
- 对SiPM阵列读出, 牺牲部分光收集效率, 分辨率影响不大, 成本可显著降低





# SiPM 阵列时间响应



## 电流反馈型运放

- ✓ 高带宽
- ✓ 高亚摆率
- ✓ 输入电容影响小

PMT: R6231-100, 2英寸

SiPM阵列: ArrayJ-30035-64P, 1英寸

## 10ns脉冲驱动LED发光测试结果

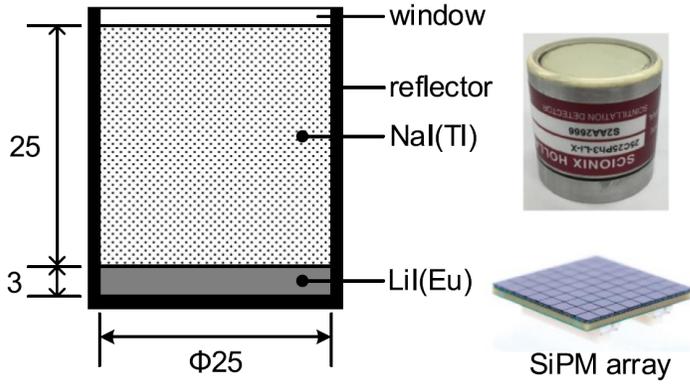
Detector	Readout circuit	Rise time (ns)	Fall time (ns)	FWHM (ns)
PMT	Oscilloscope $R_{in}=50 \Omega$	$6.2 \pm 0.2$	$16.6 \pm 0.6$	$10.1 \pm 0.2$
PMT	PMT-TIA $R_F=1000 \Omega$	$7.3 \pm 0.3$	$17.2 \pm 1.0$	$12.5 \pm 0.3$
SiPM	SiPM-V-Amp $R_L=1 \Omega$	$12.0 \pm 0.3$	$149.4 \pm 3.4$	$79.9 \pm 0.4$
SiPM	SiPM-V-Amp $R_L=5 \Omega$	$9.6 \pm 0.2$	$537.1 \pm 6.3$	$174.9 \pm 1.7$
SiPM	SiPM-V-Amp $R_L=10 \Omega$	$9.1 \pm 0.2$	$983.1 \pm 11.4$	$292.1 \pm 4.1$
SiPM	SiPM-TIA-1ch $R_F=300 \Omega$	$18.3 \pm 0.2$	$56.2 \pm 3.4$	$56.3 \pm 1.0$
SiPM	SiPM-TIA-4ch $R_F=300 \Omega$	$10.8 \pm 0.2$	$64.8 \pm 4.3$	$37.0 \pm 0.6$

$$\frac{v_o}{i} = \left[ \frac{1}{C_F \left( s + \frac{1}{R_F C_F} \right)} \right] \left[ \frac{1}{1 + \frac{R_o(C+C_F) \left( s + \frac{1}{(R_F \parallel R_o)(C+C_F)} \right)}{Z(s)C_F \left( s + \frac{1}{R_F C_F} \right)}} \right]$$

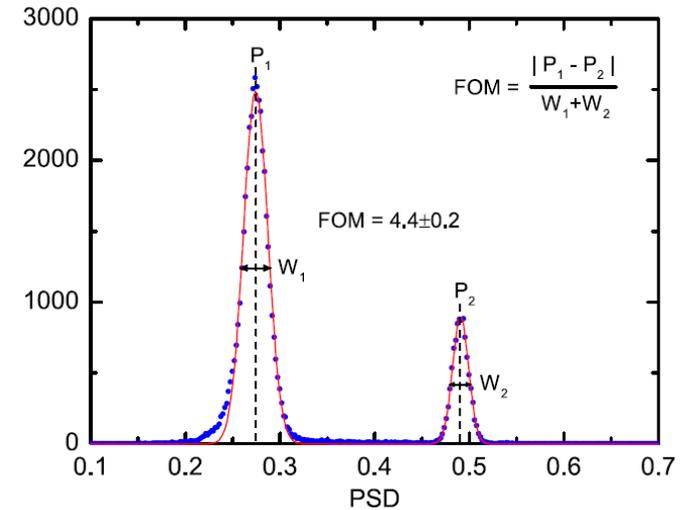
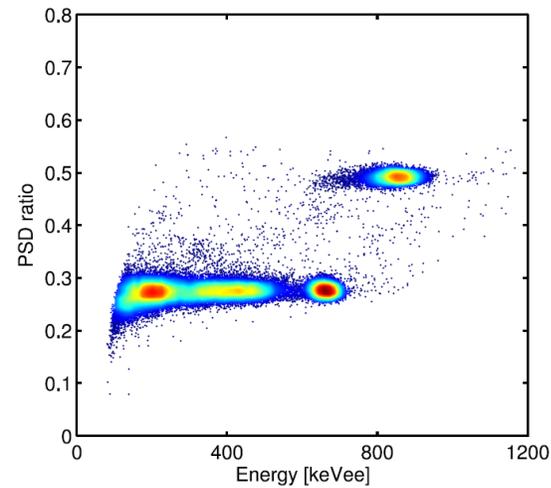
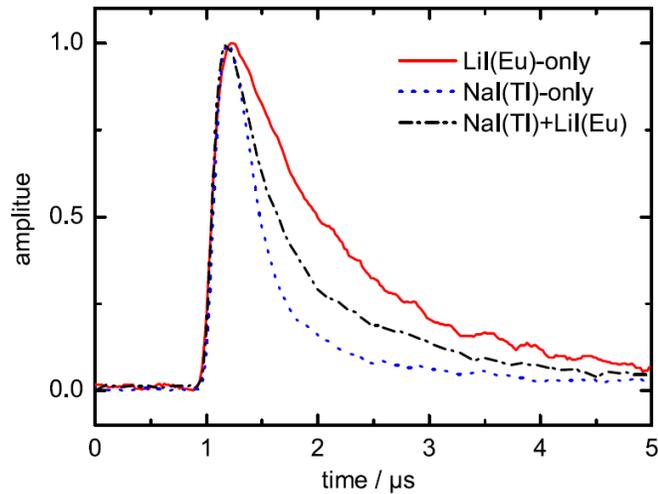
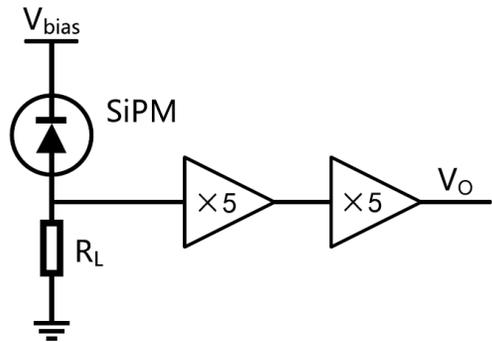
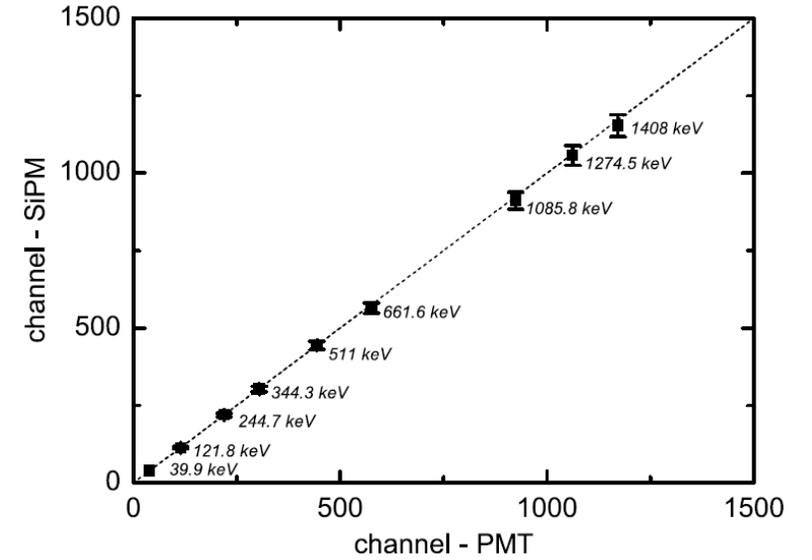
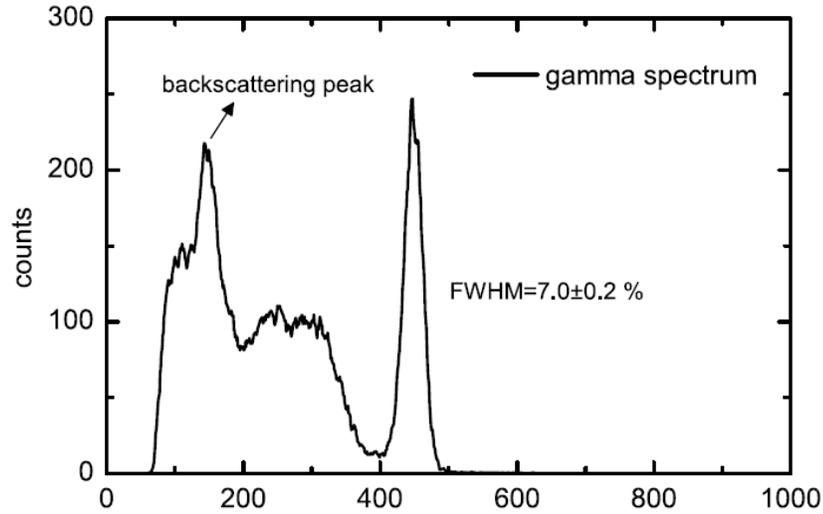


# SiPM + NaI/LiI

NIMA 881 (2018) 48-52



晶体：1英寸NaI/LiI组合晶体  
SiPM阵列：ArrayJ-30035-64P



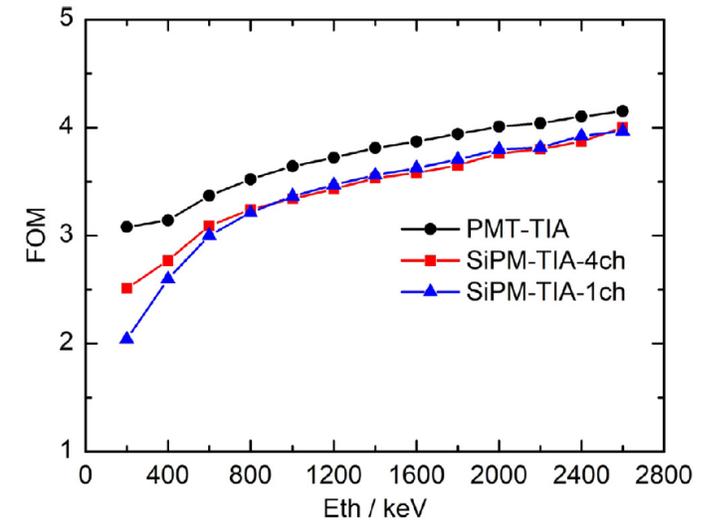
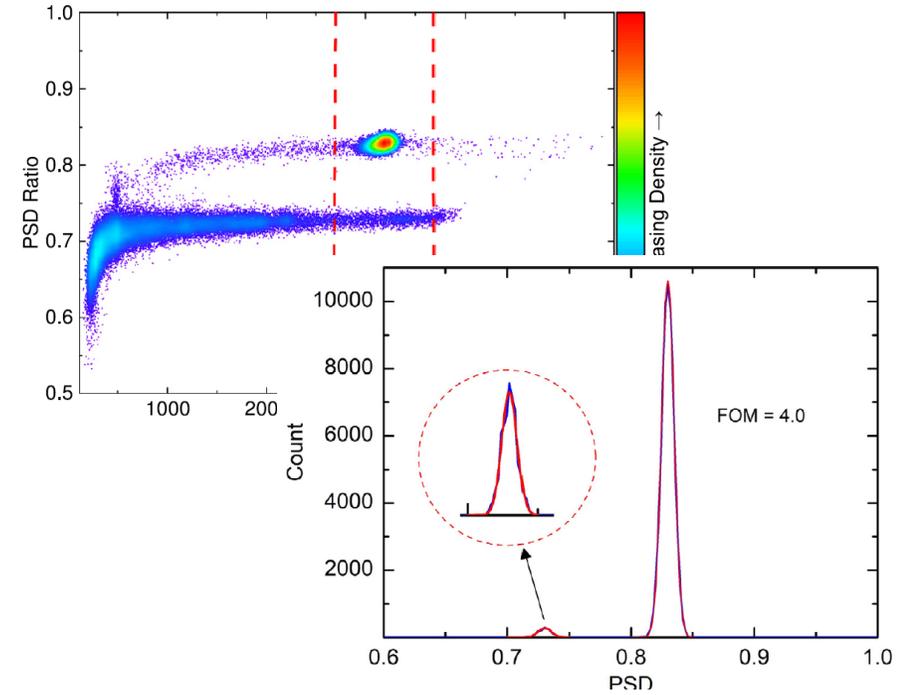
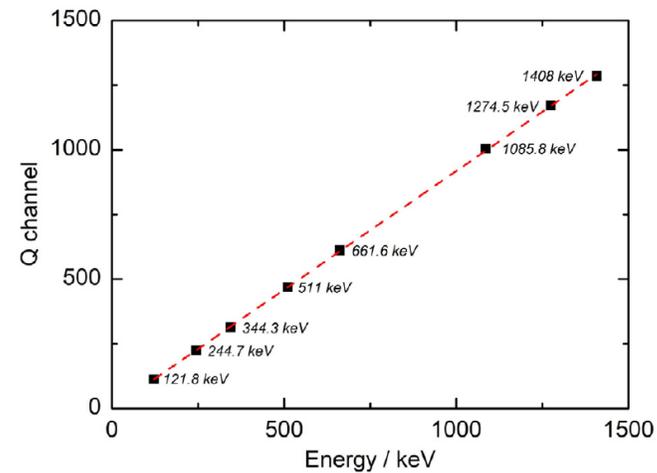
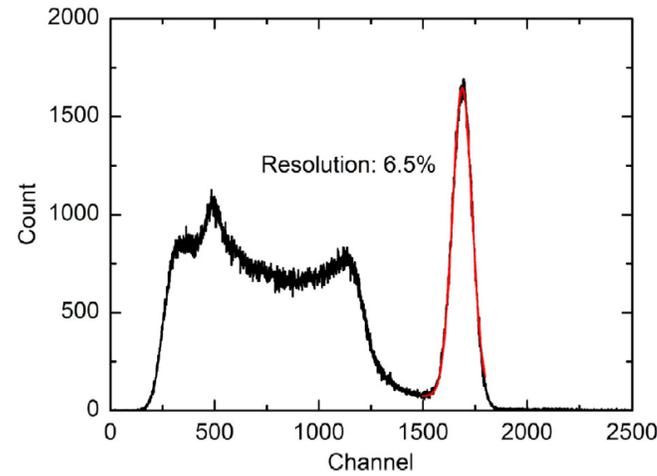
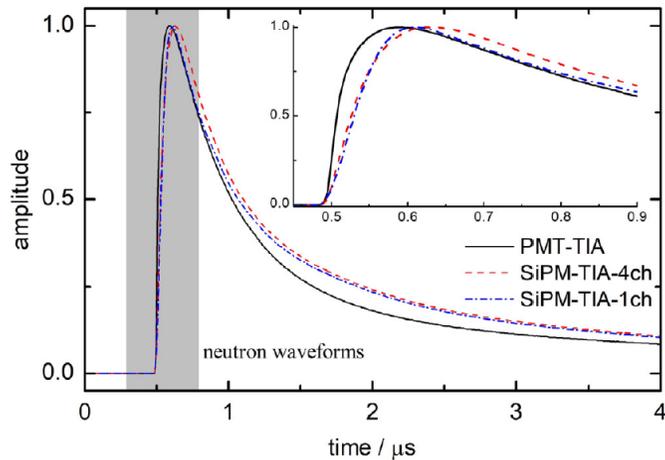
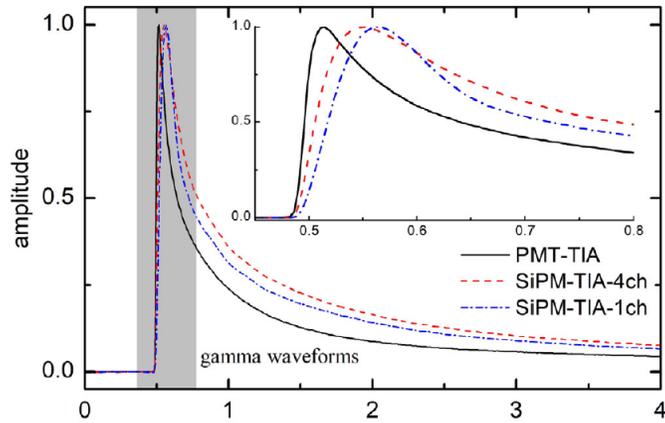


# SiPM + CLYC

NIMA 999 (2021) 165225

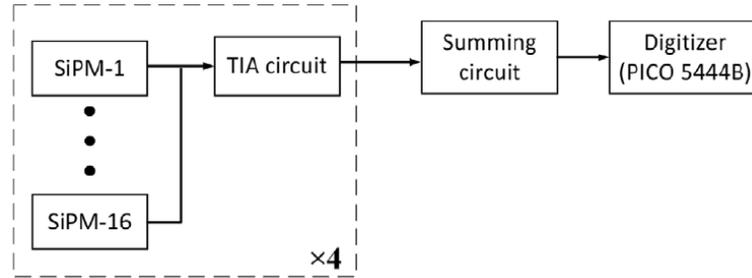


晶体: 1英寸CLYC  
PMT: R6231-100, 2英寸  
SiPM阵列: ArrayJ-30035-64P



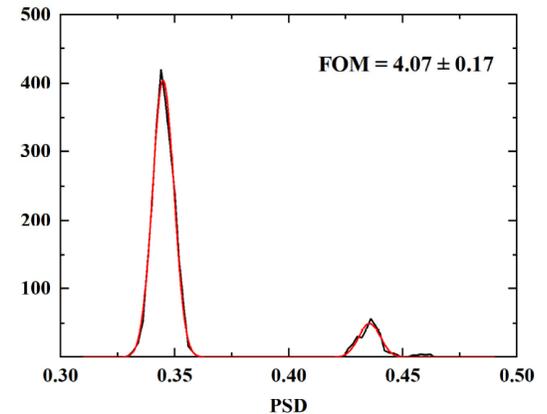
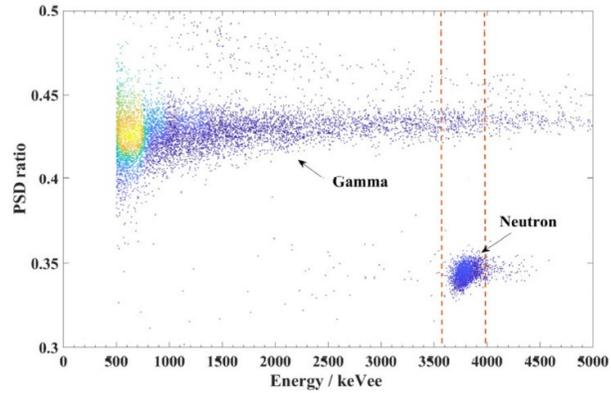
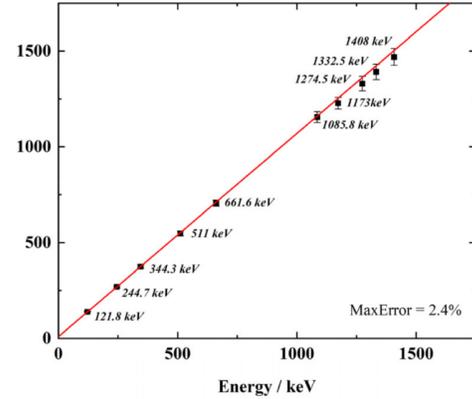
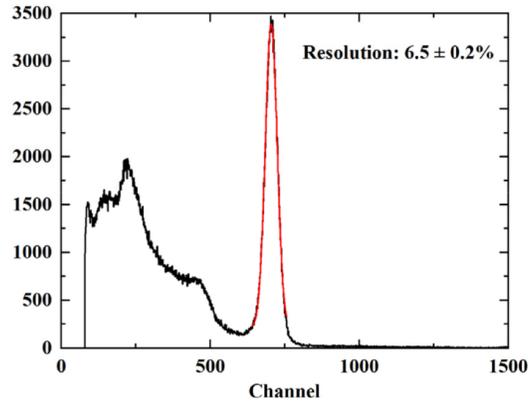


# SiPM + NaI(Tl+Li)

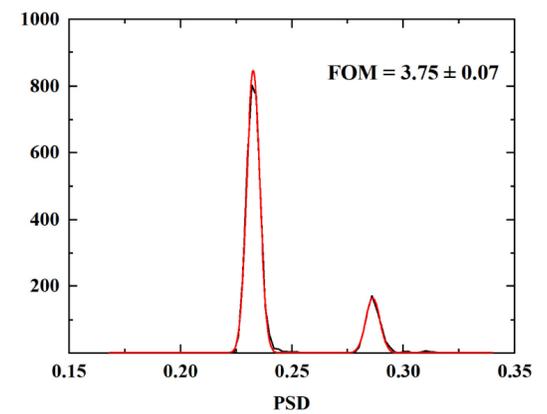
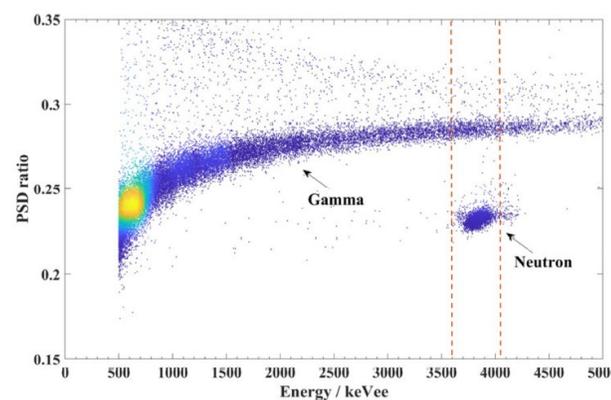
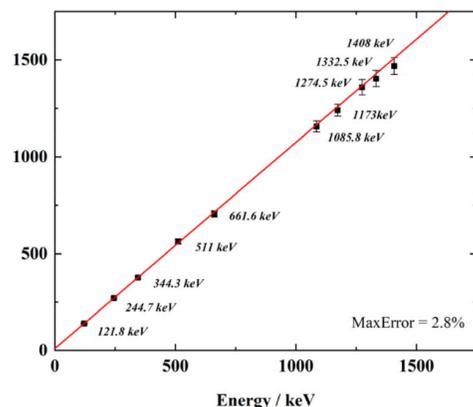
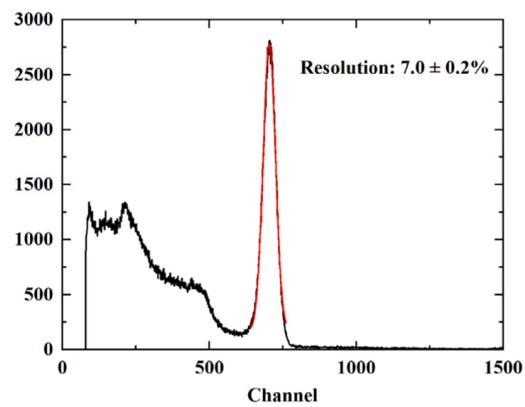


晶体: 2英寸NaI(Tl+Li)  
 PMT: R6231-100, 2英寸  
 SiPM阵列: ArrayJ-60035-64P

PMT



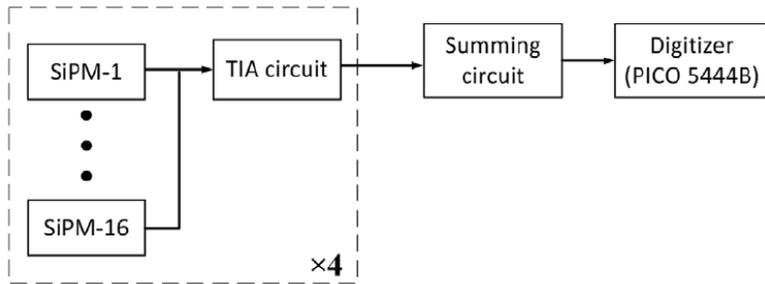
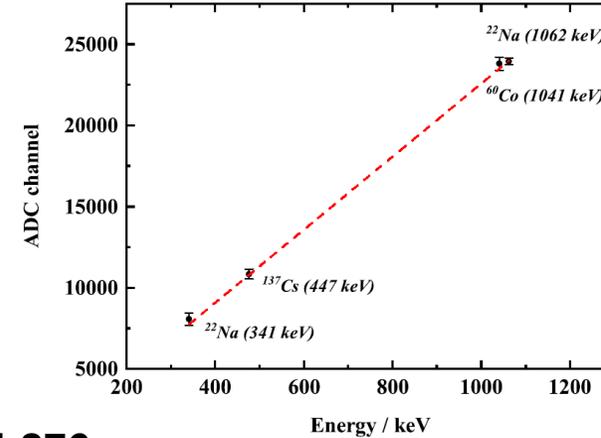
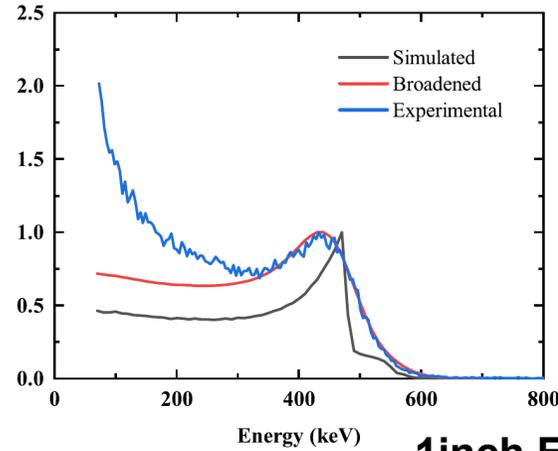
SiPM



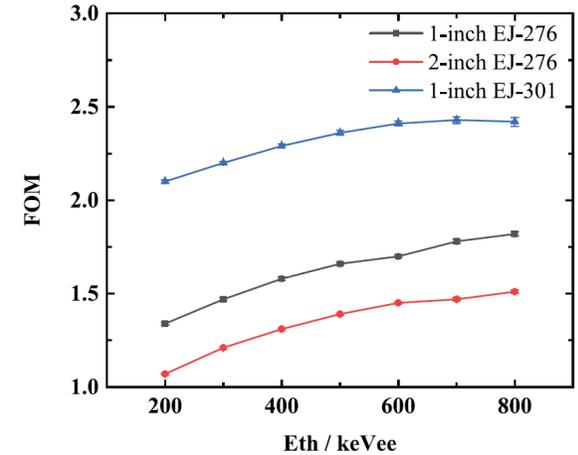
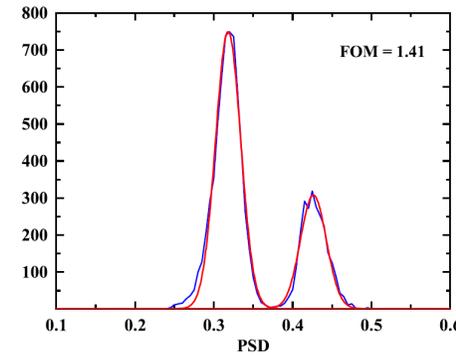
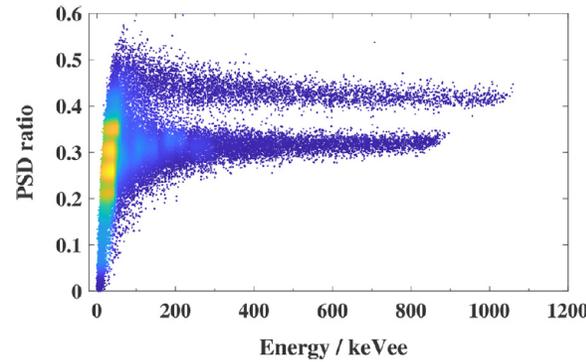


# SiPM + EJ276

NIMA 1039 (2022) 167148



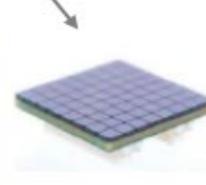
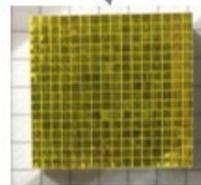
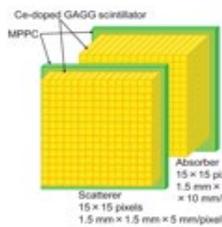
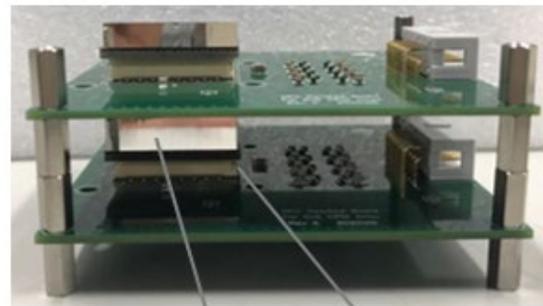
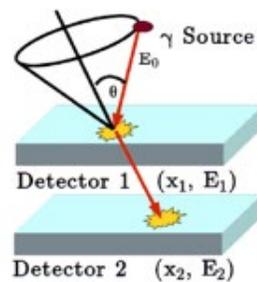
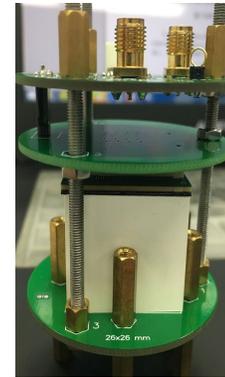
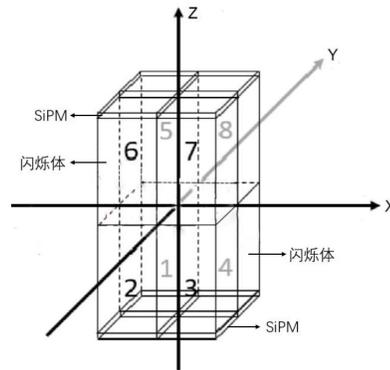
1inch EJ-276



	This work			Ferrulli et al. [17]	Grodzicka-Kobylka et al. [7]			P.V. Chuan et al. [18]
Scintillator	EJ-276	EJ-276	EJ-301	EJ-276	EJ-276	EJ-276	EJ-301	EJ-301
	$\Phi 1 \times 1$ inch	$\Phi 2 \times 2$ inch	$\Phi 1 \times 1$ inch	$\Phi 1 \times 1$ inch	$\Phi 2 \times 2$ inch	$\Phi 1 \times 1$ inch	$\Phi 2 \times 2$ inch	$\Phi 34 \times 60$ mm
Photodetector	SiPM Array	SiPM Array	SiPM Array	SiPM Array	PMT	PMT	PMT	PMT
Source	AmBe	AmBe	AmBe	AmBe	PuBe	PuBe	PuBe	$^{252}\text{Cf}$
FOM	1.41	1.15	2.15	1.10	1.78	1.93	2.94	1.29
	( $\geq 250$ keVee)	(270–330 keVee)	(270–330 keVee)	(270–330 keVee)	( $\geq 300$ keVee)			



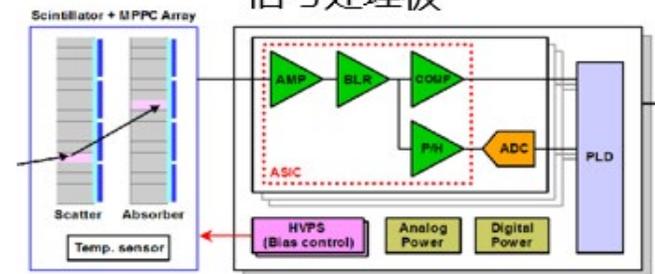
# 拓展应用：无人机核探测系统



GAGG晶体

SiPM阵列

信号处理板



谢谢大家!