西北工业大学
NORTHWESTERN POLYTECHNICAL UNIVERSITY

面向背景粒子筛除的智能化CMOS像素探测器研发

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第三届全国辐射探测微电子学术交流会

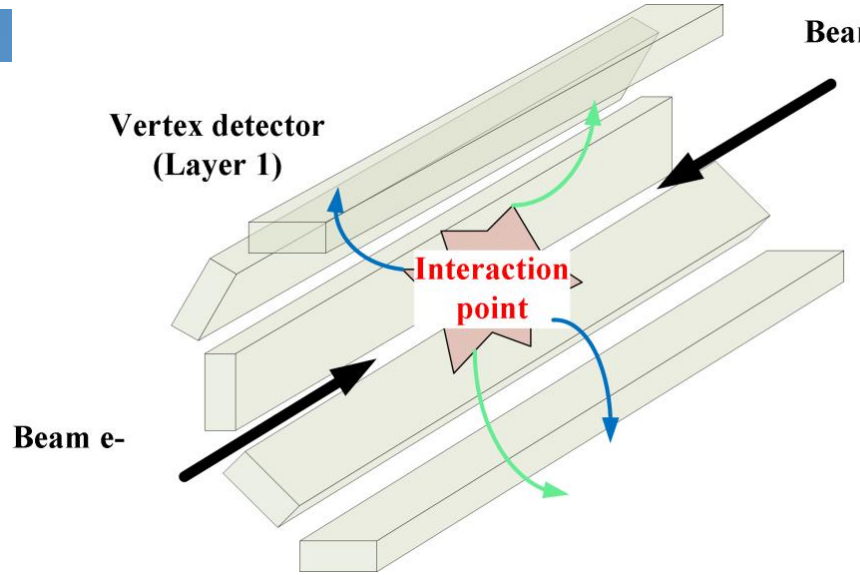
2023年10月22日

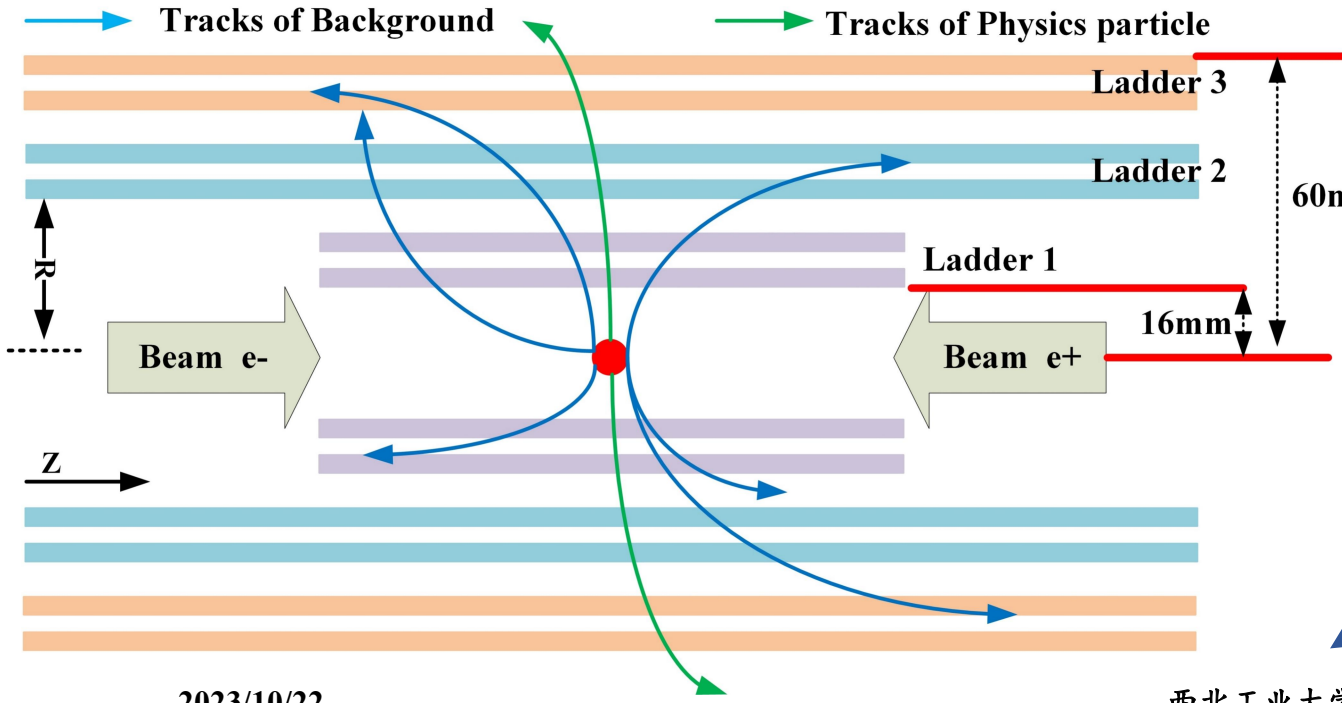
目录

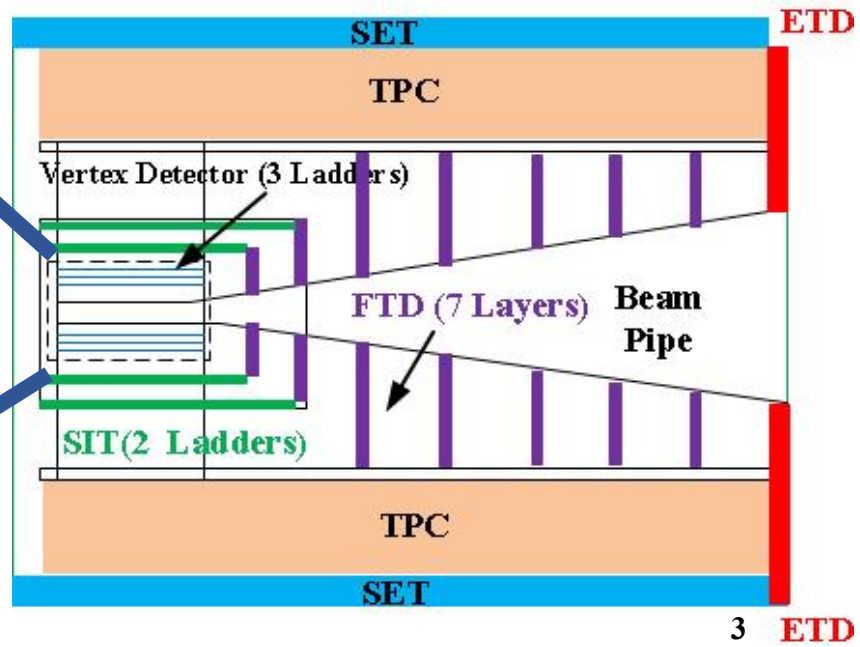
1.研究动机

国际直线对撞机（ILC）中背景束产生的带电粒子在顶点探测器产生大量额外命中。

导致探测器系统数据量急剧上升。





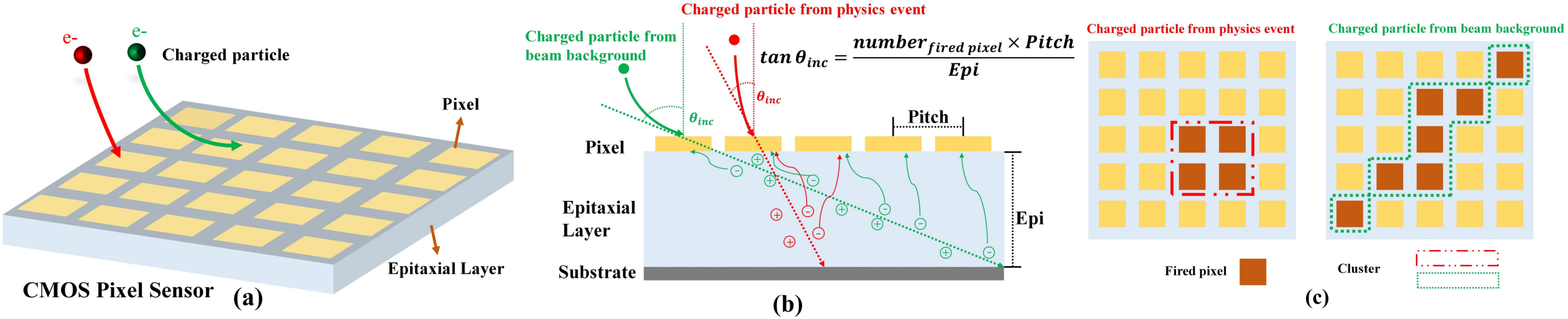


1.研究动机

背景束粒子具有较小动量（10~100MeV）

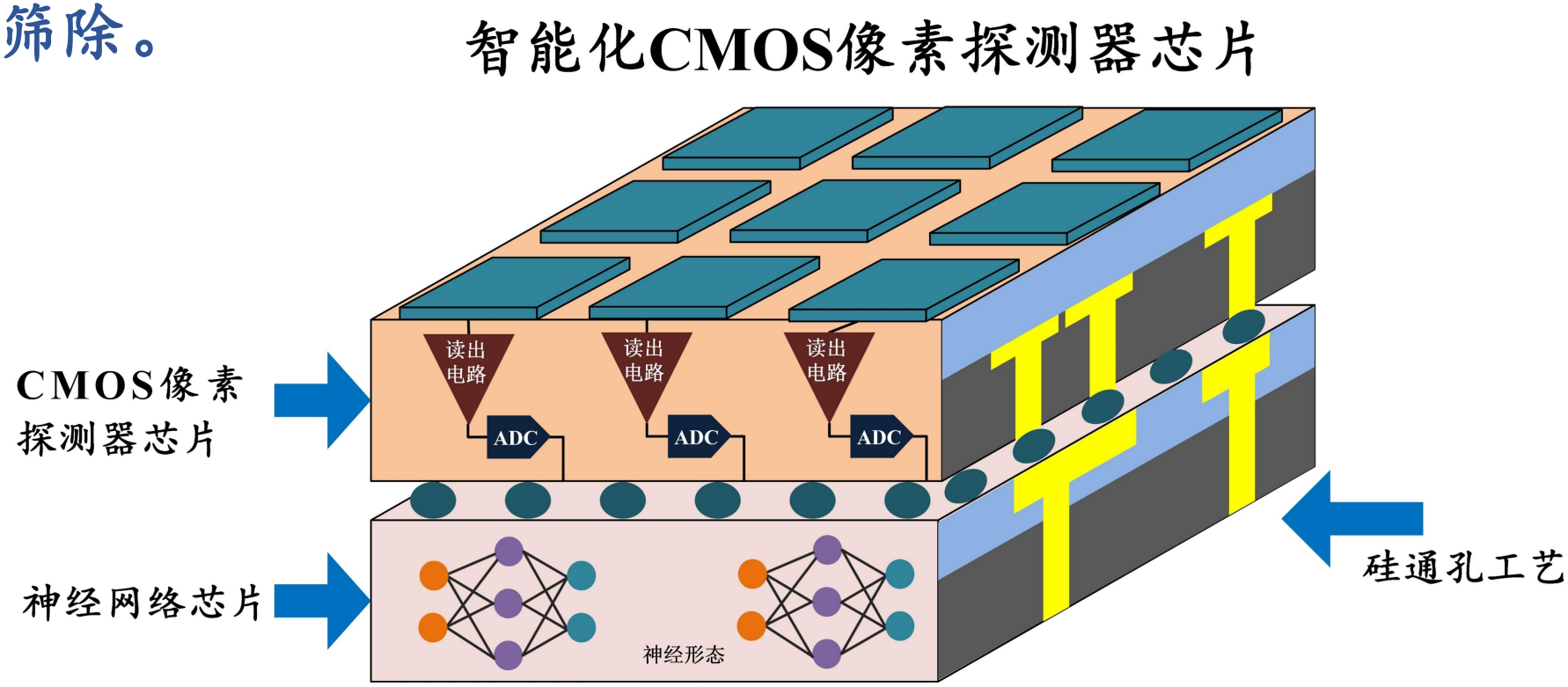
在CMOS像素探测器表面形成较大的入射角度

产生具有细长形状特征的cluster

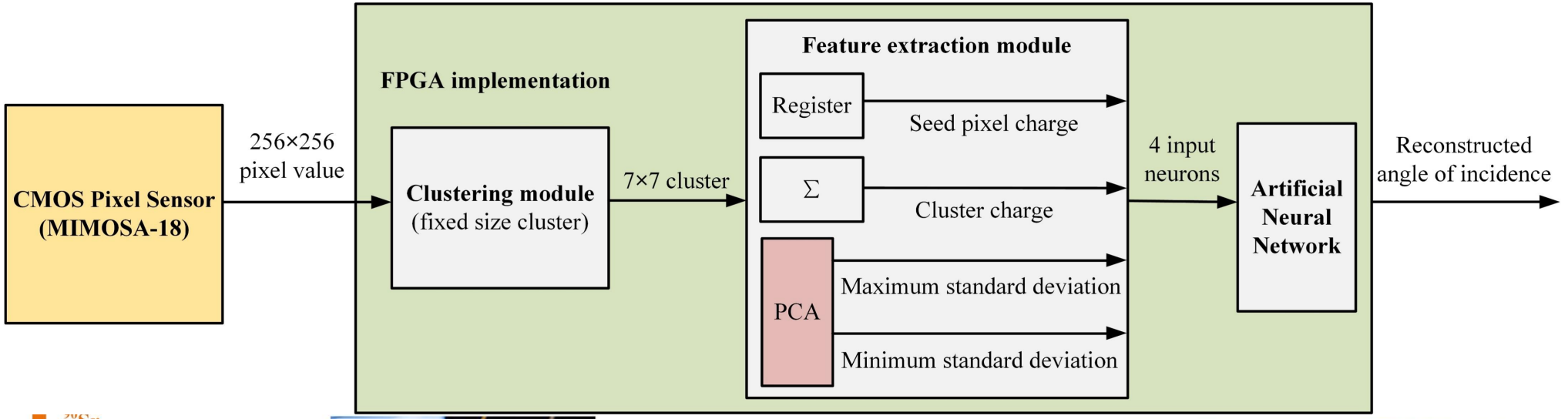


2.研究内容

通过集成人工神经网络结构的智能化CMOS像素探测器，实现背景束命中的片上筛除。

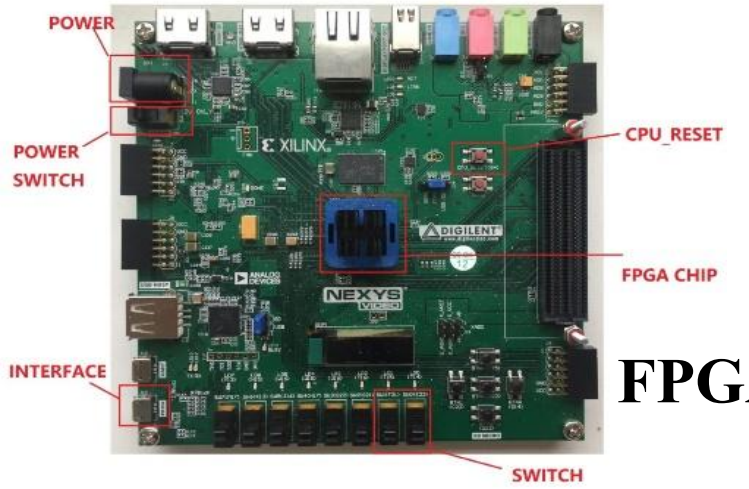


3.研究进展-验证性研究



不同角度cluster分布获取系统

MIMOSA-18

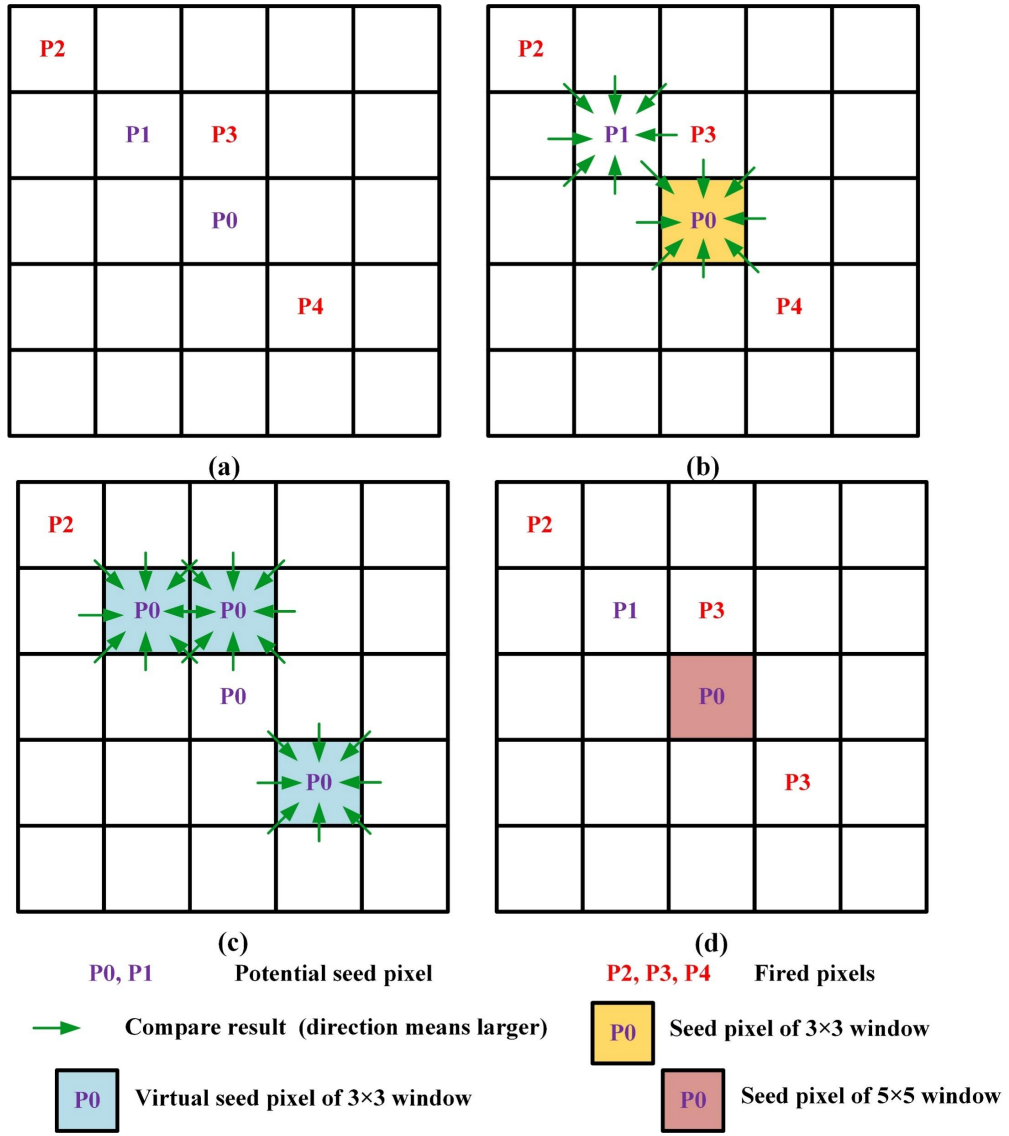


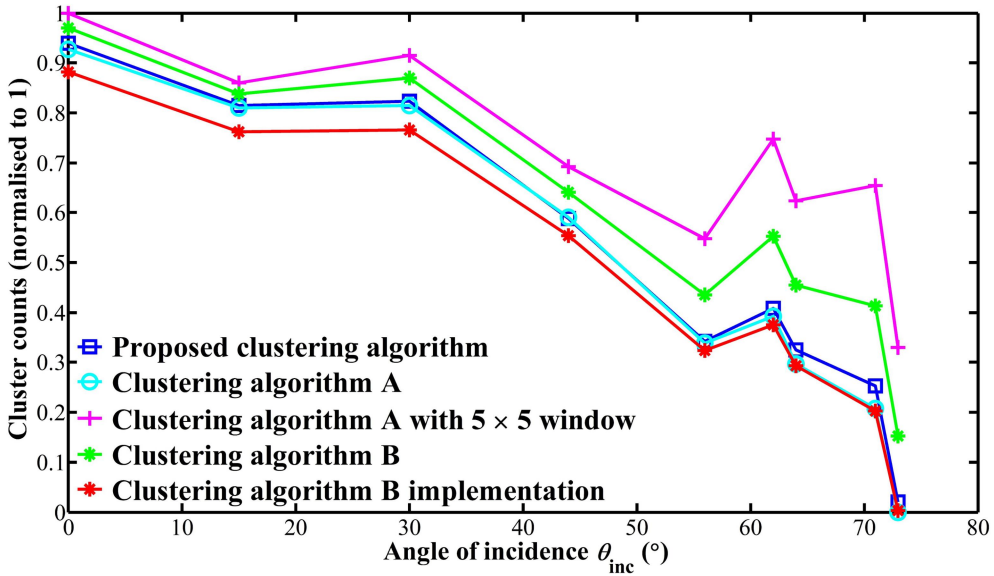
FPGA开发板

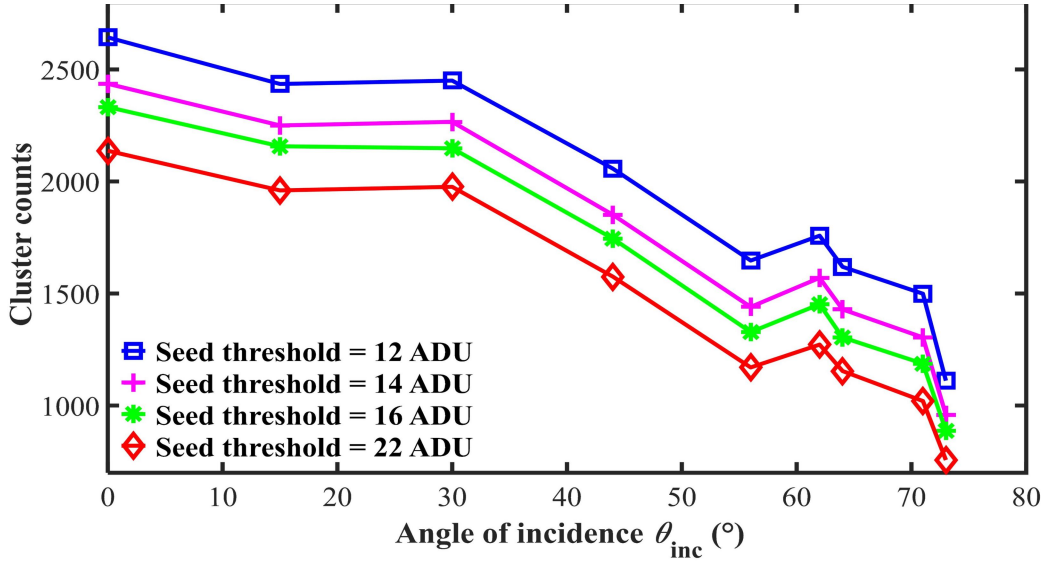
FPGA Implementation of an Artificial Neural Network for Subatomic Physics Experiment Particles Recognition

3.研究进展-像素级Clustering算法

像素级ADC的Clustering片上集成算法示意图

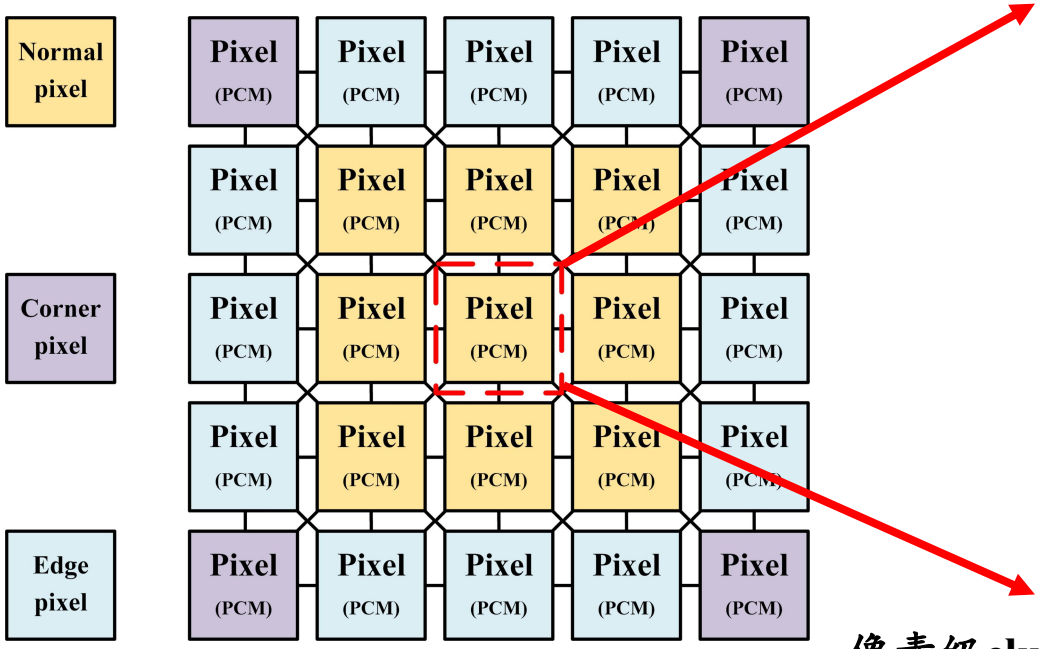


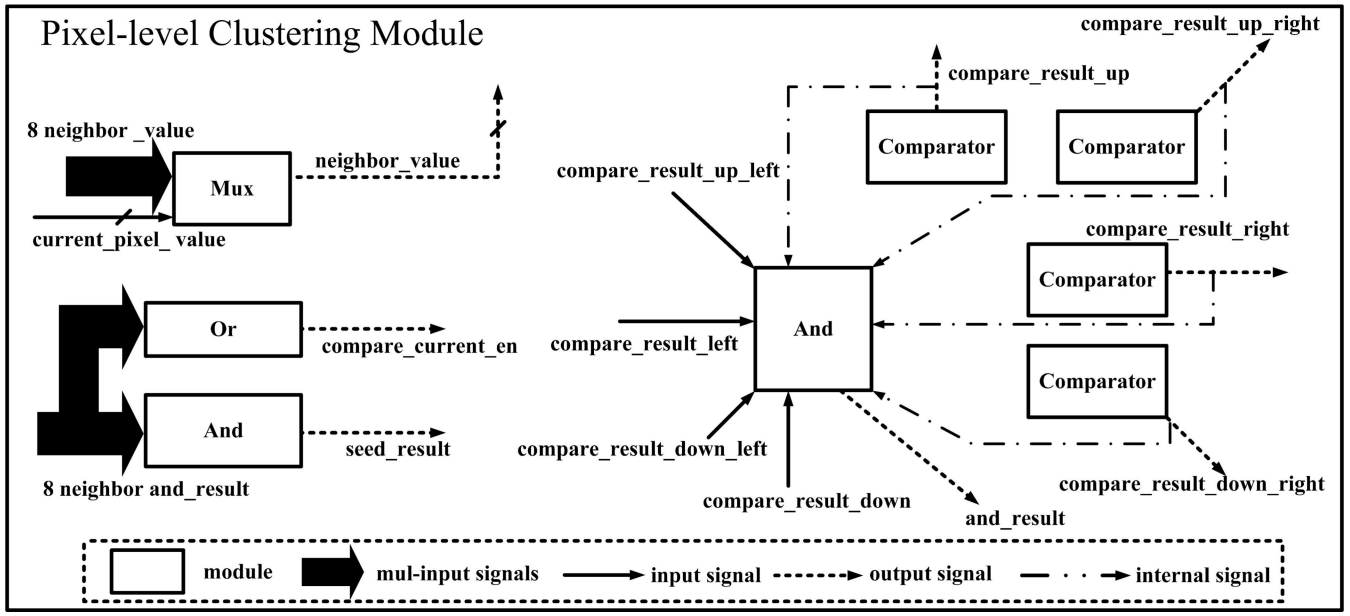




"Pixel-level clustering algorithm for data reconstruction in ILC", 投稿*IEEE Trans. Nucl. Sci*

3.研究进展-像素级Clustering算法

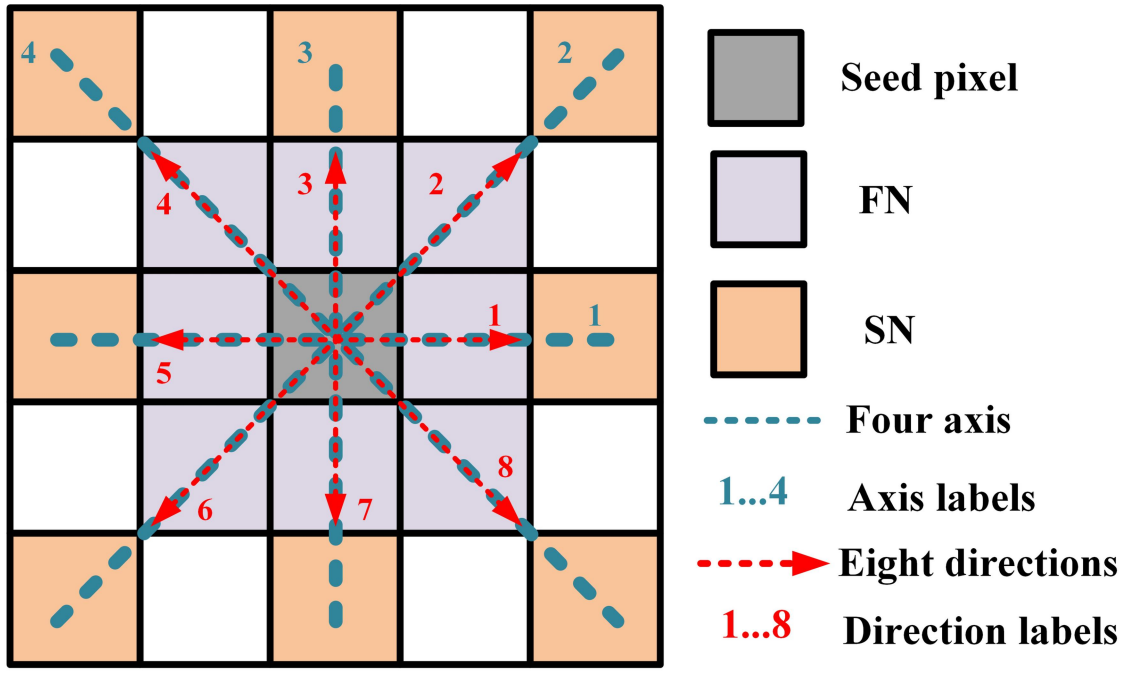




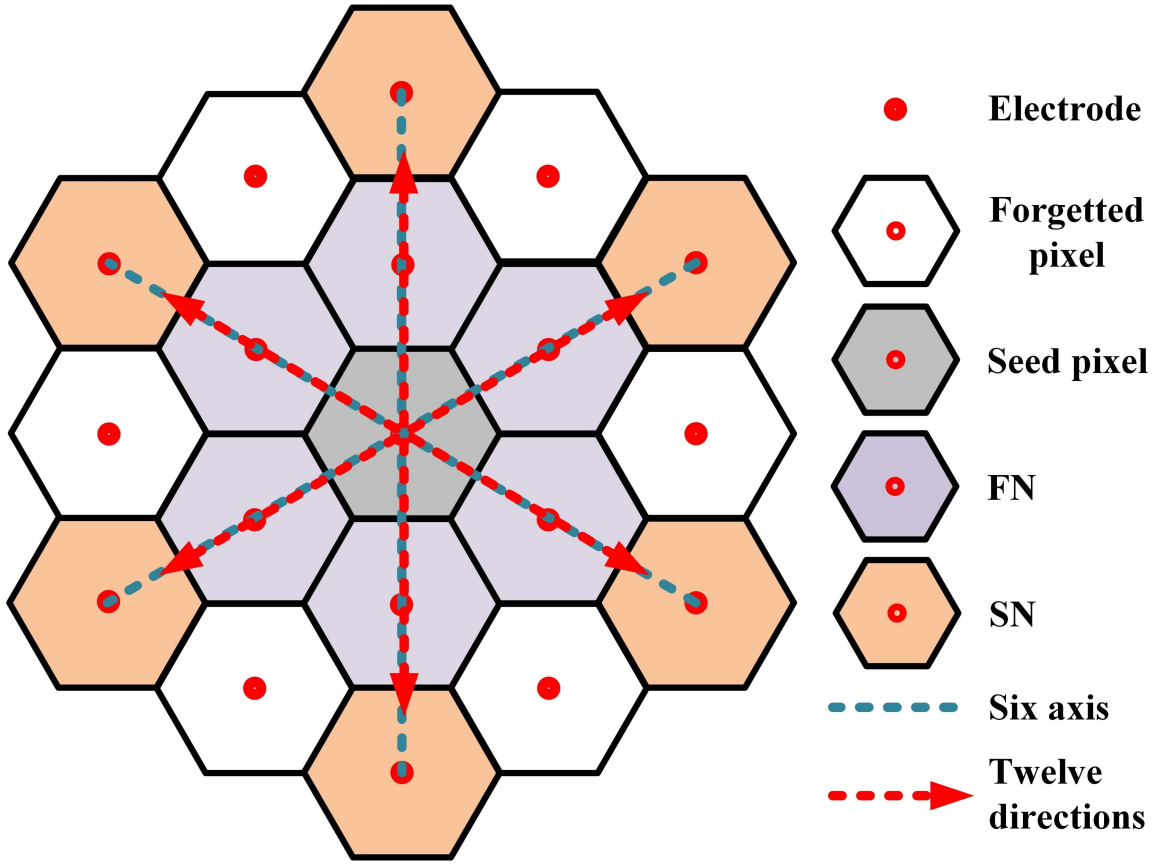
像素级clustering算法像素内结构

Type		ADC (bit)	Clock (Mhz)	Area (μm^2)	Power (mW)
5×5 matrix		4	100	72592.09	7.04
	Edge pixel (up)	4	100	2483.74	0.26
	Corner pixel (down_left)	4	100	2511.96	0.31
	Normal pixel	4	100	3537.45	0.34
5×5 matrix		4	200	73637.40	13.87
5×5 matrix		8	100	111994.59	10.41

3.研究进展-轻量化特征提取算子

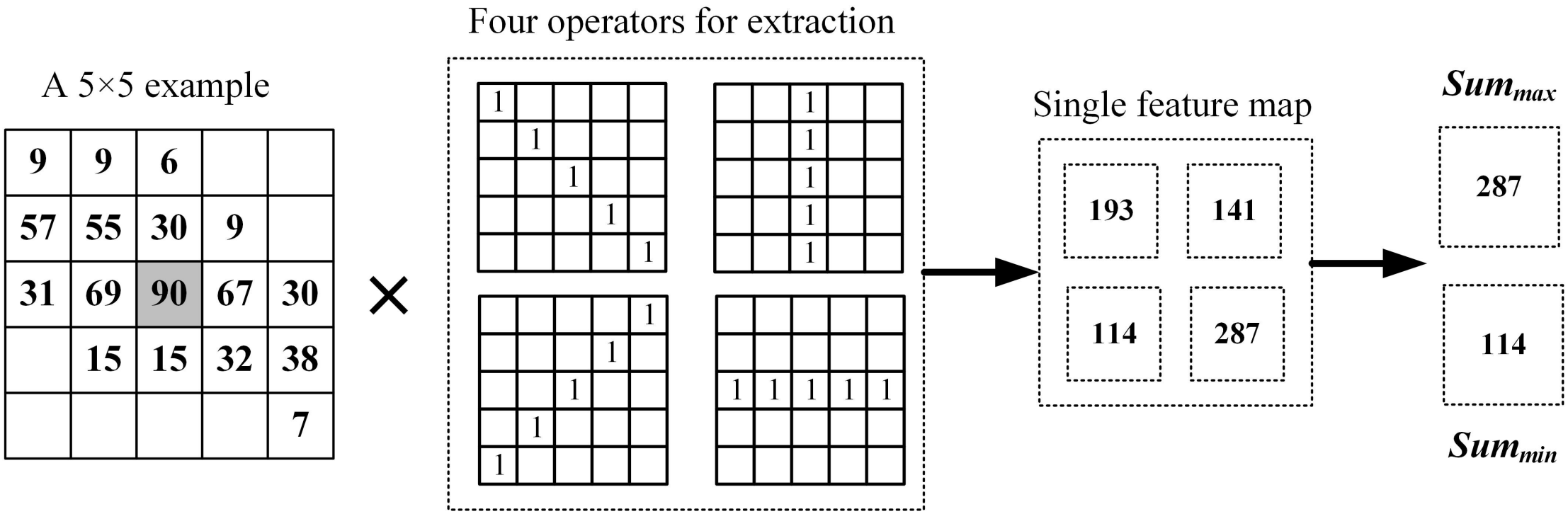


传统像素布局特征



六边形像素布局特征

3.研究进展-轻量化特征提取算子



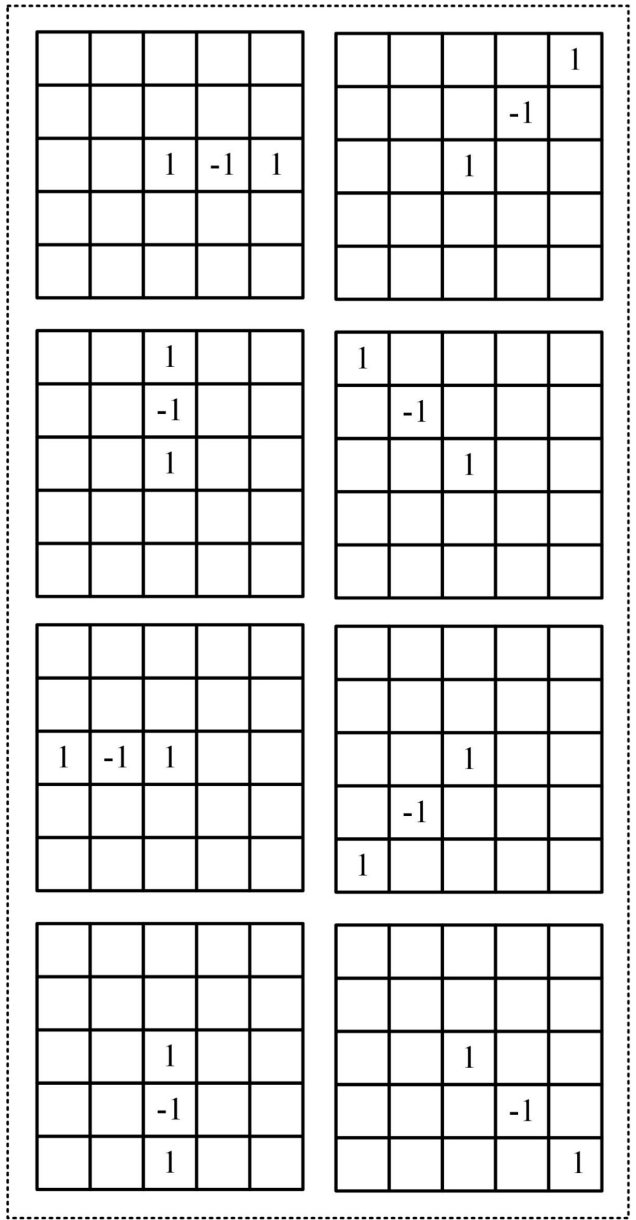
四轴像素幅值分布特征提取示例

$$\begin{cases} Sum_{\max} = \max(f(i)) \\ Sum_{\min} = \min(f(i)) \\ f(i) = \sum_{n=1}^{5} \text{pixel charge}_{i,n}, \end{cases} \quad i = (1, 2, 3, 4).$$

“Performance Analysis of Compact On-Chip Operators for Cluster Feature Extraction”, *IEEE Trans. Nucl. Sci*接收

3.研究进展-轻量化特征提取算子

Eight operators for extraction



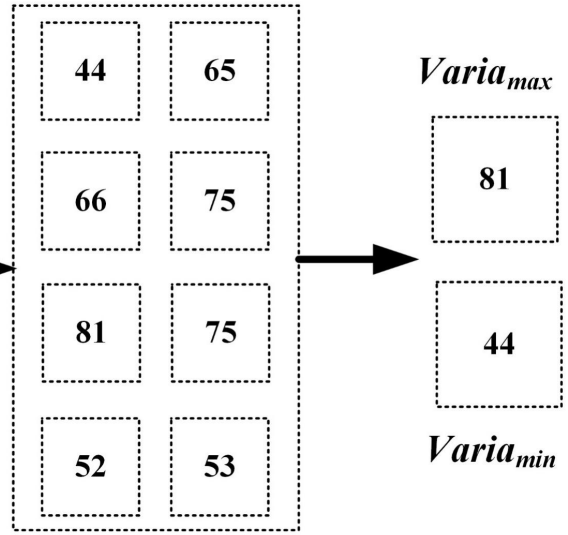
A 5×5 example

9	9	6		
57	55	30	9	
31	69	90	67	30
	15	15	32	38
				7

×

$$\left\{\begin{array}{c} Varia_{max} = max\left(f(k)\right) \\ Varia_{min} = min\left(f(k)\right) \\ f(k) = pixel\ charge_{k,3} - pixel\ charge_{k,2} + pixel\ charge_{k,1} \end{array}\right\}$$

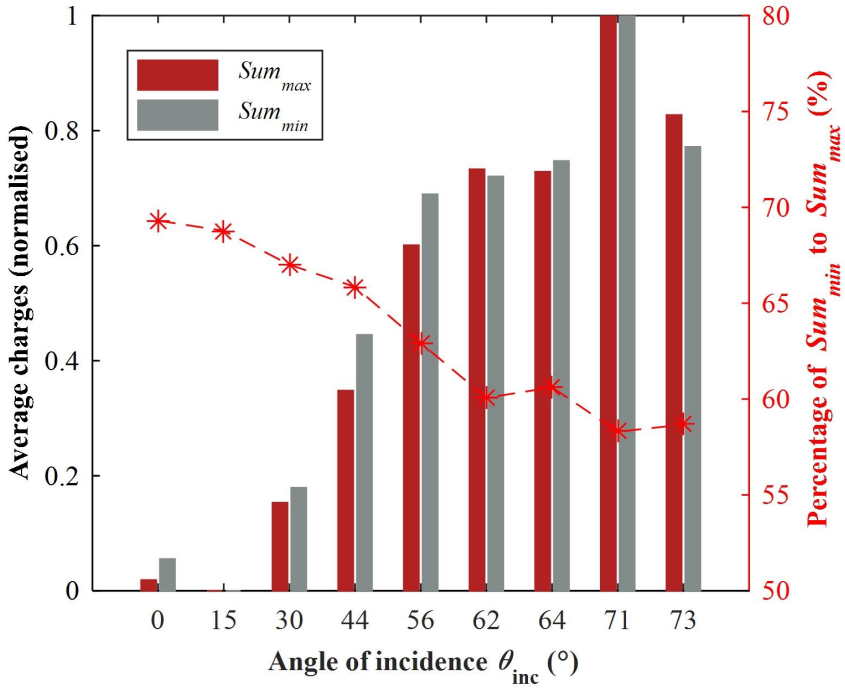
Single feature map

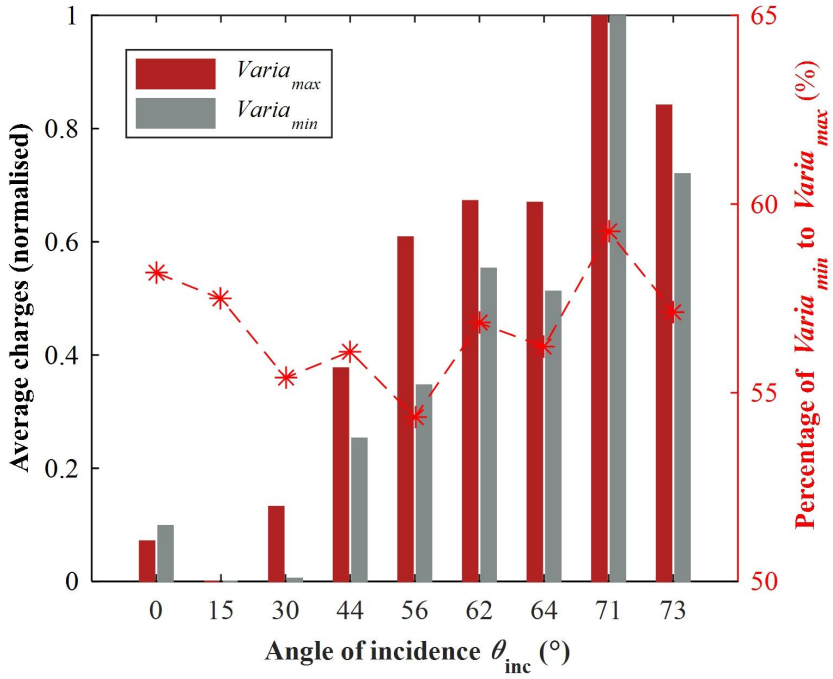


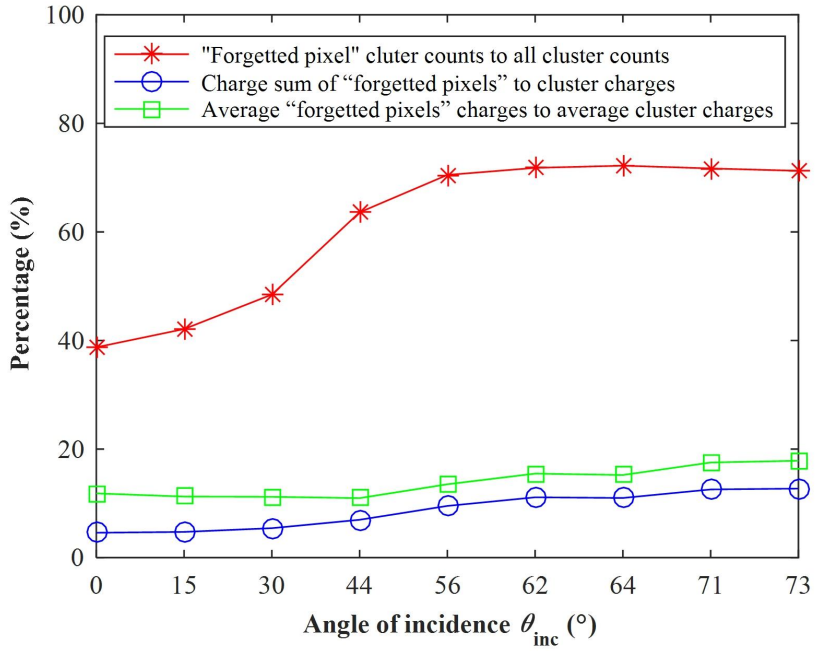
八方向像素幅值分布特征提取示例

“Performance Analysis of Compact On-Chip Operators for Cluster Feature Extraction”, *IEEE Trans. Nucl. Sci*接收

3.研究进展-轻量化特征提取算子







算法提取特征分布仿真结果

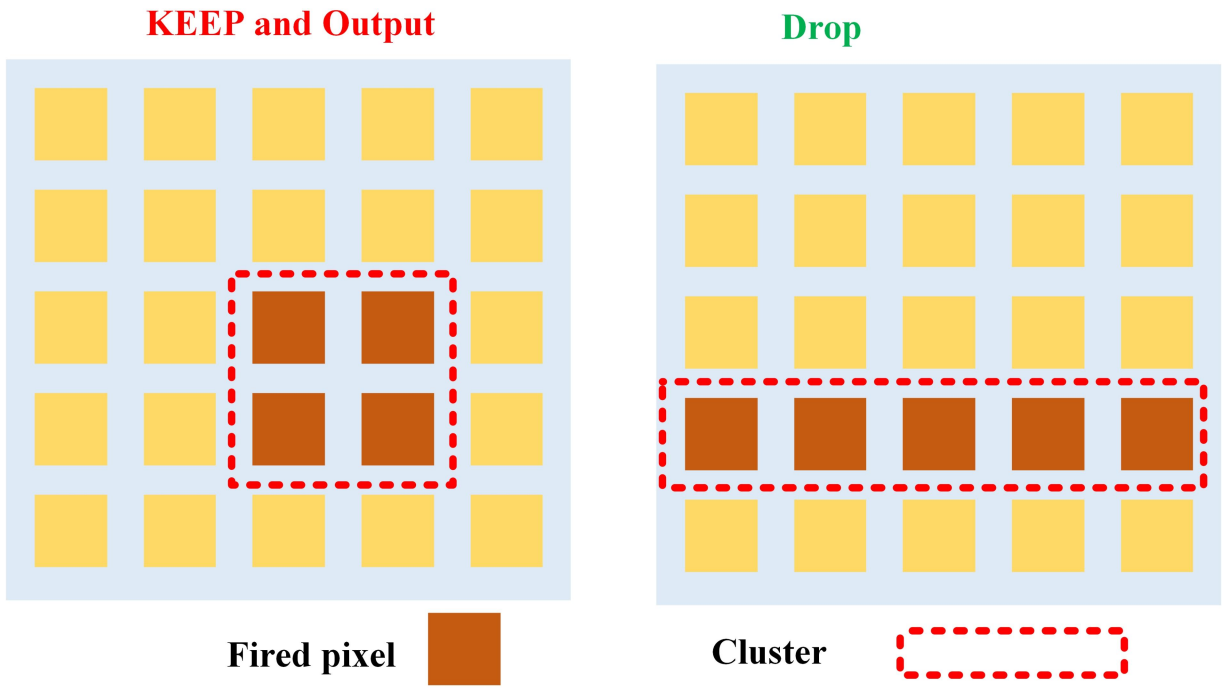
"Performance Analysis of Compact On-Chip Operators for Cluster Feature Extraction", *IEEE Trans. Nucl. Sci*接收

3.研究进展-算法推广

数据压缩及命中cluster筛除

1. 鉴别器输出， Hit / not Hit

2. 细长/集中形cluster鉴别



4.总结与展望

总结

- 开发了面向片上集成的像素级clustering算法及电路结构
- 设计了轻量化的cluster分布特征提取算法及电路结构

展望

- 研究多变量耦合下cluster部分模型
- 建立MLP训练平台
- 针对六边形像素布局开展相关研究

谢谢

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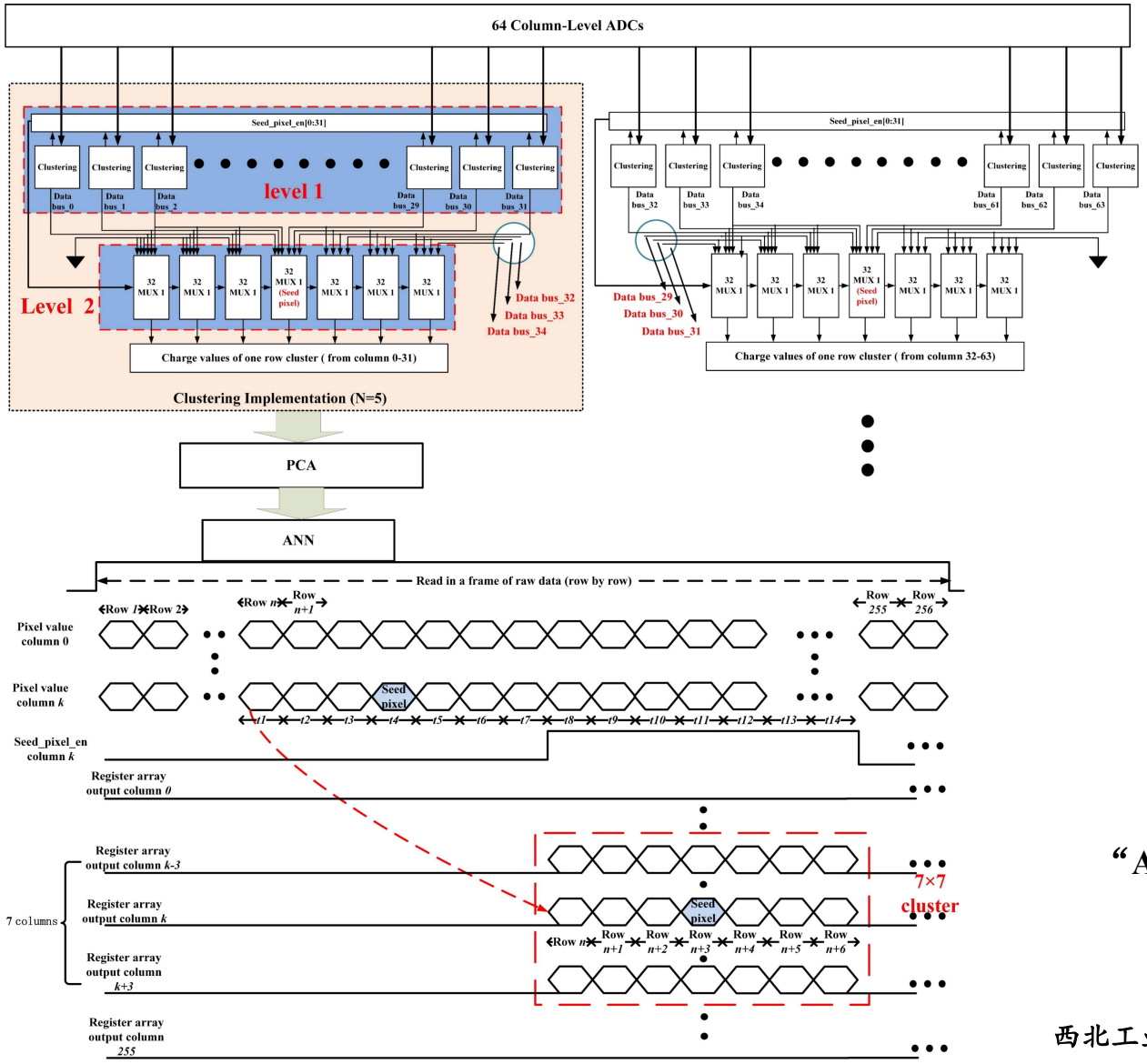
Backup



Window	Multiplexer	ADC (bits)	Clock (MHz)	Column height (μm)	Column power (mW)
7×7	16-1	8	100	200.58	0.85
		8	200	200.15	1.83
		4	100	102.86	0.46
		4	200	103.39	0.88
7×7	32-1	8	100	197.81	0.86
		8	200	197.24	1.77
		4	100	101.08	0.43
		4	200	102.24	0.88
5×5	32-1	8	100	159.39	0.68
		8	200	159.2	1.45
		4	100	81.56	0.37
		4	200	82.92	0.71
7×7	64-1	8	100	196.83	0.87
		8	200	196.09	1.76
		4	100	101.26	0.43
		4	200	101.63	0.9

“A 2-D Clustering Algorithm for Data Reconstruction in Vertex Detector of ILC”