



中国科学院高能物理研究所  
Institute of High Energy Physics  
Chinese Academy of Sciences



# 季度考核报告

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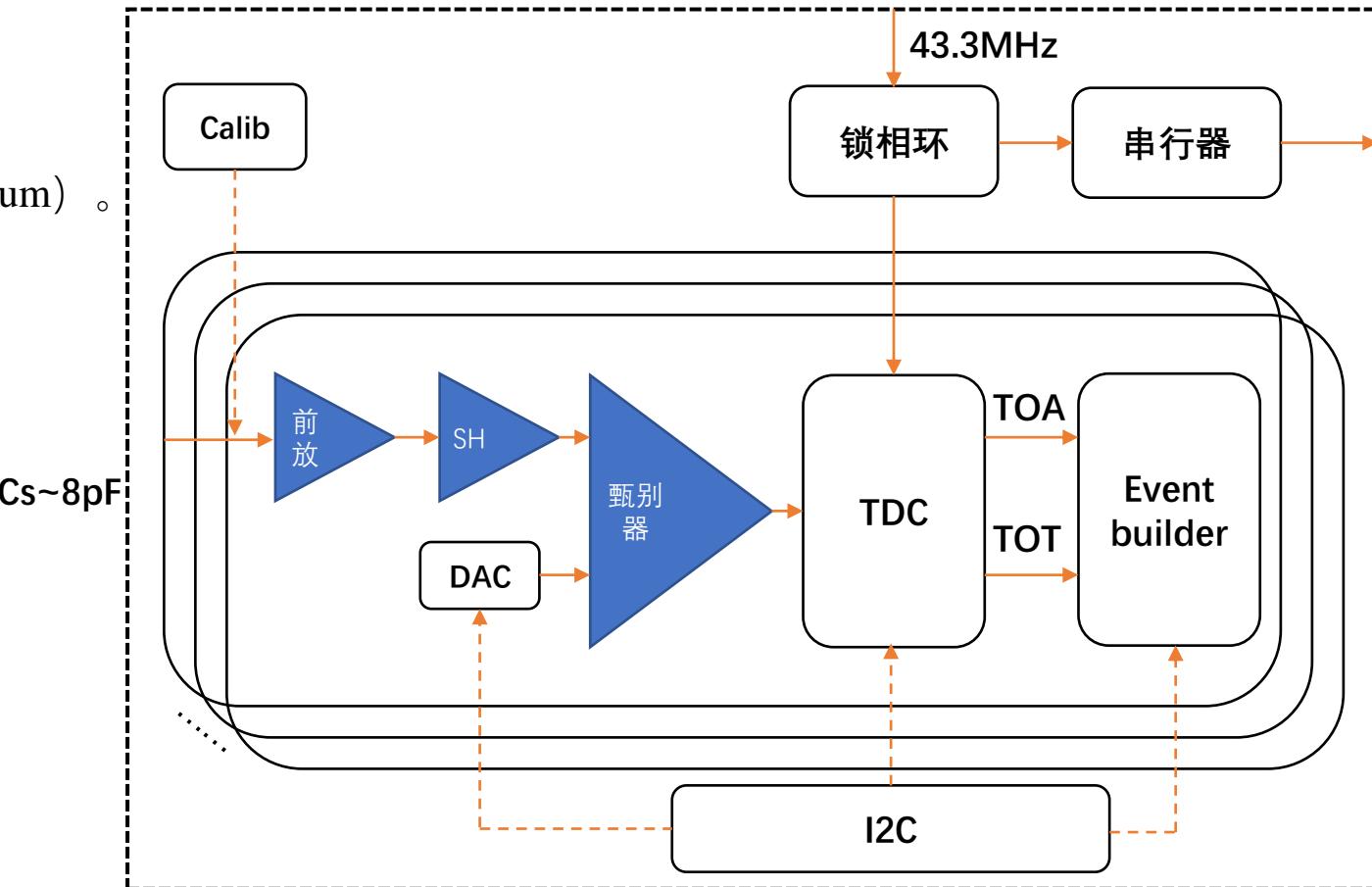
**Electronics**

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## ■ 项目背景

- CEPC外围径迹探测器——OTK
  - 传感器——AC\_LGAD;
  - 高精度时间（系统50 ps）和高位置分辨（10 um）。
- OTK读出芯片（LATRIC）芯片性能需求：
  - 小面积，128通道，单通道高度100 um;
  - 低功耗，单通道功耗20 mW;
  - 高分辨，时间分辨30 ps。



LATRIC框图

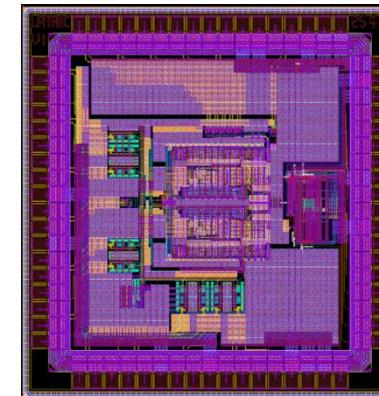
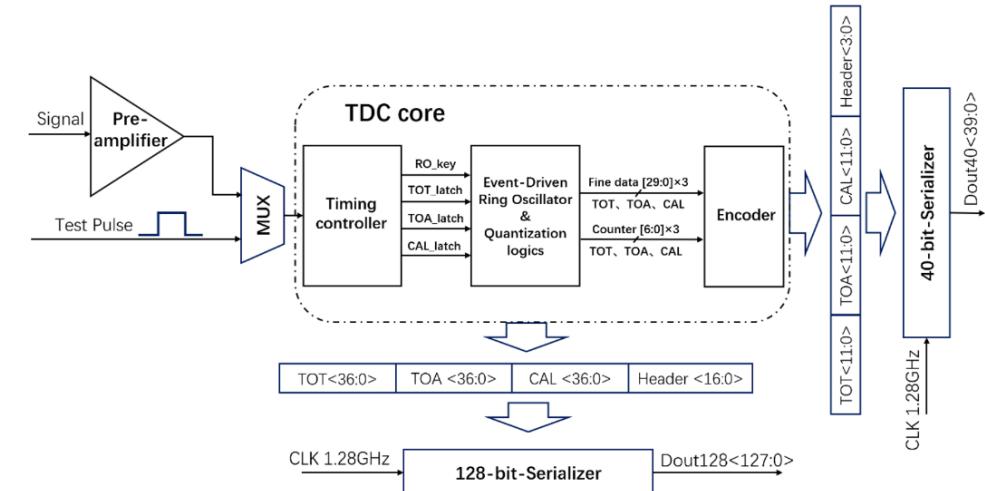
## ■ 测试芯片LATRICO

## ➤ 芯片结构

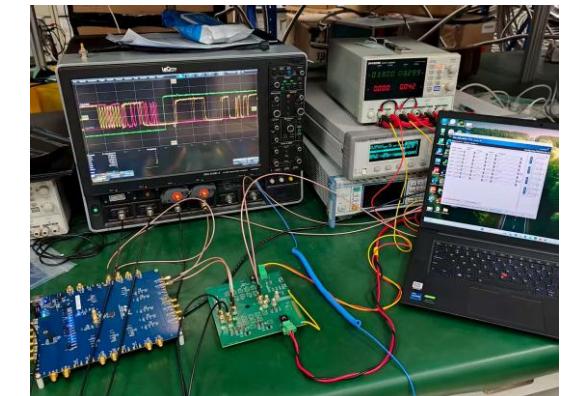
- 为实现核心模块功能验证, 包括前放、TDC、编码器、128位串行器、40位串行器五部分;
- Test pulse 与前放输出选通后作为待测信号;
- TDC的量化输出编码前后分别由128位串行器、40位串行器串行输出, 两者对照用于气泡问题研究, 以及Encoder可靠性验证;

## ➤ 测试方案

- 时钟板触发信号发生器, 调整skew和pulse width 扫描TOA和TOT转移曲线;



LATRIC-V0 layout

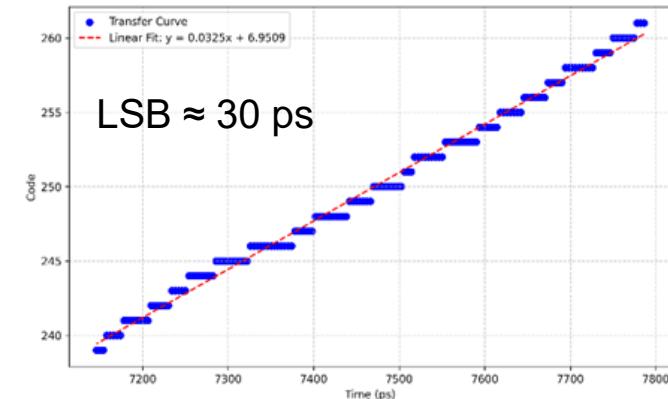
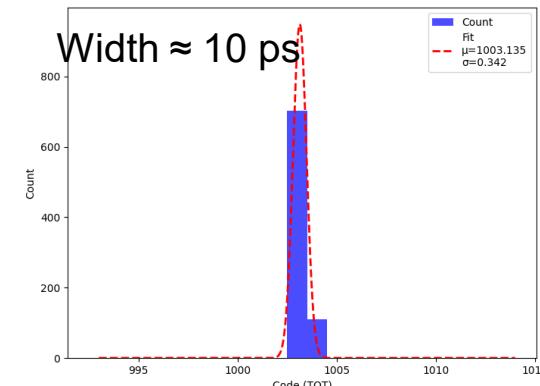
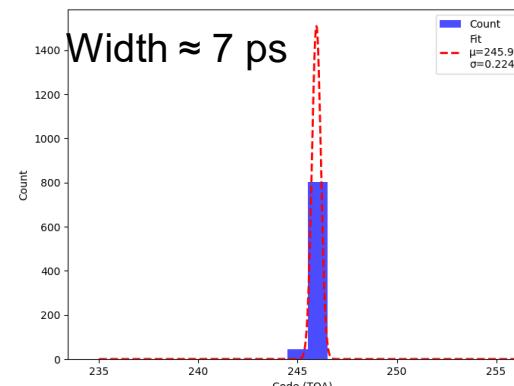




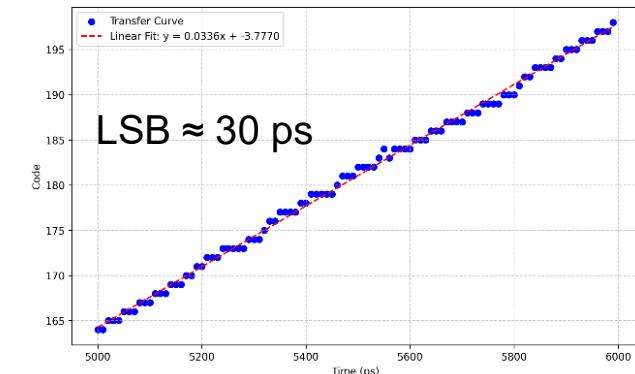
## ■ 测试芯片LATRICO

### ➤ 测试结果

- 时间分辨: 拟合  $LSB \approx 29.762 \text{ ps}$ , 芯片自刻度给出  $LSB \approx 29.756 \text{ ps}$ , 满足时间分辨需求, 验证了芯片自刻度功能;
- 多次测量 $\sigma$  好于  $0.5LSB$ ;
- TDC core功耗: 2M事例率  $0.5\text{mA}$  ( $1.2\text{V}$ ) , 1M事例率  $0.3\text{mA}$  ( $1.2\text{V}$ ) , 500k事例率  $0.1\text{mA}$  ( $1.2\text{V}$ )
- TOT : DNL  $\pm 0.7LSB$ , INL  $-0.9LSB \sim 0.6LSB$ ;
- TOA: DNL  $-0.6LSB \sim 0.8LSB$ , INL  $\pm 0.8LSB$ 。



TOA测试转移曲线 (step 4ps)



TOT测试转移曲线 (step 10ps)

## ■ 测试芯片LATRICO 指标对比

参数	需求	测试结果
工艺	SMIC55	
LSB	30ps	29.76ps
量化精度	15ps	(LSB* $\sigma$ ) 14.82ps
测量范围	TOT: 50ps~50ns TOA: 0~23.09ns	<ul style="list-style-type: none"> <li>• TOT 150ps~114ns (低于200ps 暂未测量)</li> <li>• TOA 0~114ns</li> </ul>
INL/DNL	$\pm 1$ LSB	<ul style="list-style-type: none"> <li>• TOT : DNL <math>\pm 0.7</math>LSB, INL -0.9LSB~0.6LSB</li> <li>• TOA: DNL -0.6LSB~0.8LSB, INL <math>\pm 0.8</math>LSB</li> </ul>
功耗	单通道<20 mW	<ul style="list-style-type: none"> <li>• TDC core 2M事例率工作电流 0.5mA (1.2V)</li> <li>• 前放 4.9mA (1.2V)</li> <li>• 多通道Event builder 10月流片后给出测量结果</li> </ul>

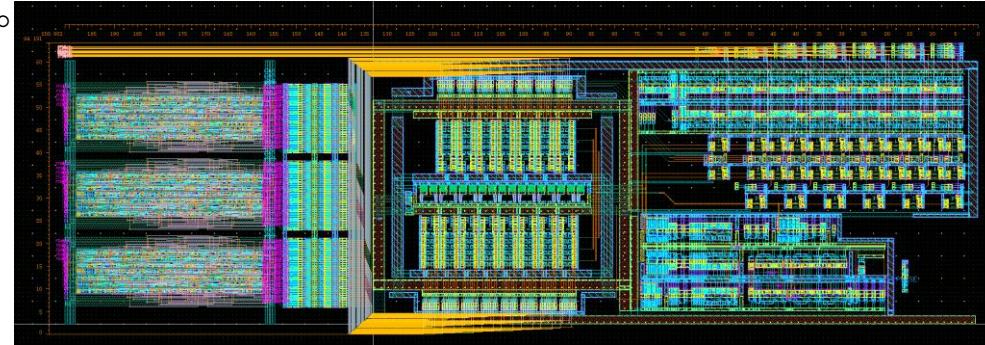


## ■ 八通道芯片 LATIC1 (十月流片)

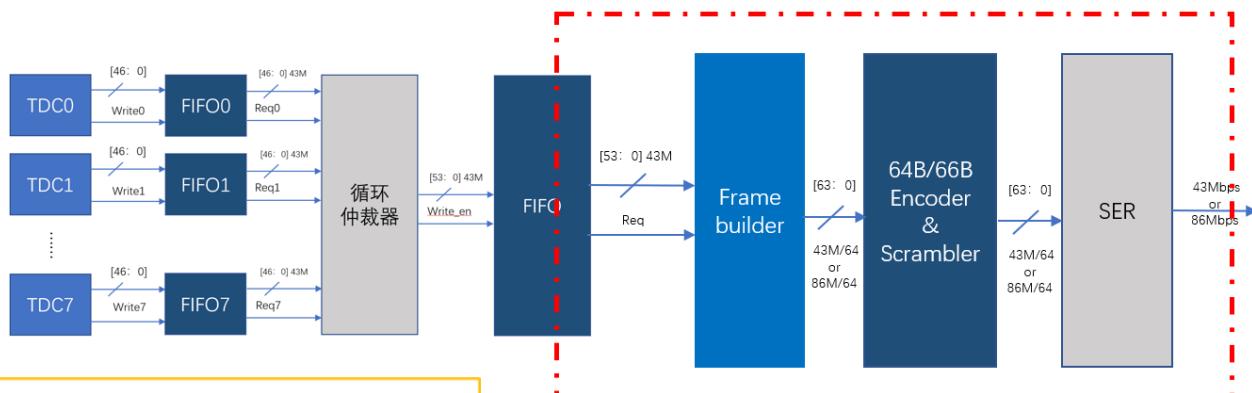
- 单通道TDC core, layout高度 **64.2 um**, 尚余 35.8 um做通道间隔离。
- 单通道数据, 含时间戳:  $10 + 11 + 12 + 14 + 7 = 54$ 位;
  - TOT, TOA, CAL细计数均为5位;
  - TOA:  $(23.09 \text{ ns} + 5 \text{ ns}) / (0.024 \text{ ns} * 30)$   
 $\approx 39$   
 粗计数6位 ( $2^6 = 64$ )
  - CAL:  $(23.09 \text{ ns} + 23.09 \text{ ns} + 5 \text{ ns}) / (0.024 \text{ ns} * 30)$   
 $\approx 71$   
 粗计数为7位 ( $2^7 = 128$ )
  - TOT粗计数为5位, 则量程为 $(2^5) * (0.024 \text{ ns} * 30) = 23.04 \text{ ns}$

### ➤ 按照128通道总击中率计算串行输出速率:

- 端盖总击中率  $2.1 * (10^5) * 1.28 * 3.3 = 0.887 \text{ M}$ ;
- 桶部总击中率  $8 * (10^4) * 1.28 * 4.4 = 0.45 \text{ M}$ ;
- $43.3 \text{ M} / 64 = 0.677 \text{ M} > 0.450 \text{ M}$ ;
- $86.6 \text{ M} / 64 = 1.353 \text{ M} > 0.887 \text{ M}$ ;



单通道 TDC layout



Event builder框图

The supported data rate per sensor readout ASIC is up to 43.33 Mbit/s for the barrel and up to 86.67 Mbit/s for the endcap, corresponding to a maximum hit rate of  $8.0 \times 10^4 \text{ Hz/cm}^2$  for the barrel (detector active area  $\sim 1.28 \text{ cm} \times 4.4 \text{ cm}$  per ASIC) and  $2.1 \times 10^5 \text{ Hz/cm}^2$  for the endcap (detector active area  $\sim 1.28 \text{ cm} \times 3.3 \text{ cm}$  per ASIC). This detector's tolerable hit rate is  $\sim 5$  times larger than the estimated maximum background hit rate for the OTK barrel (OTKB,  $1.56 \times 10^4 \text{ Hz/cm}^2$ ) and  $\sim 5$  times larger than that for the OTK endcap at Low Lumi Z (OTKE,  $4.41 \times 10^4 \text{ Hz/cm}^2$ ), as summarized in Table 5.18.



## ■ 后续工作

- 十月流片，八通道LATRIC1，Event builder前端验证，及八通道顶层工作；
- TWEPP poster
- 文章



# Thank you!