应用于CBM-ToF装置的密封型垫片式MRPC

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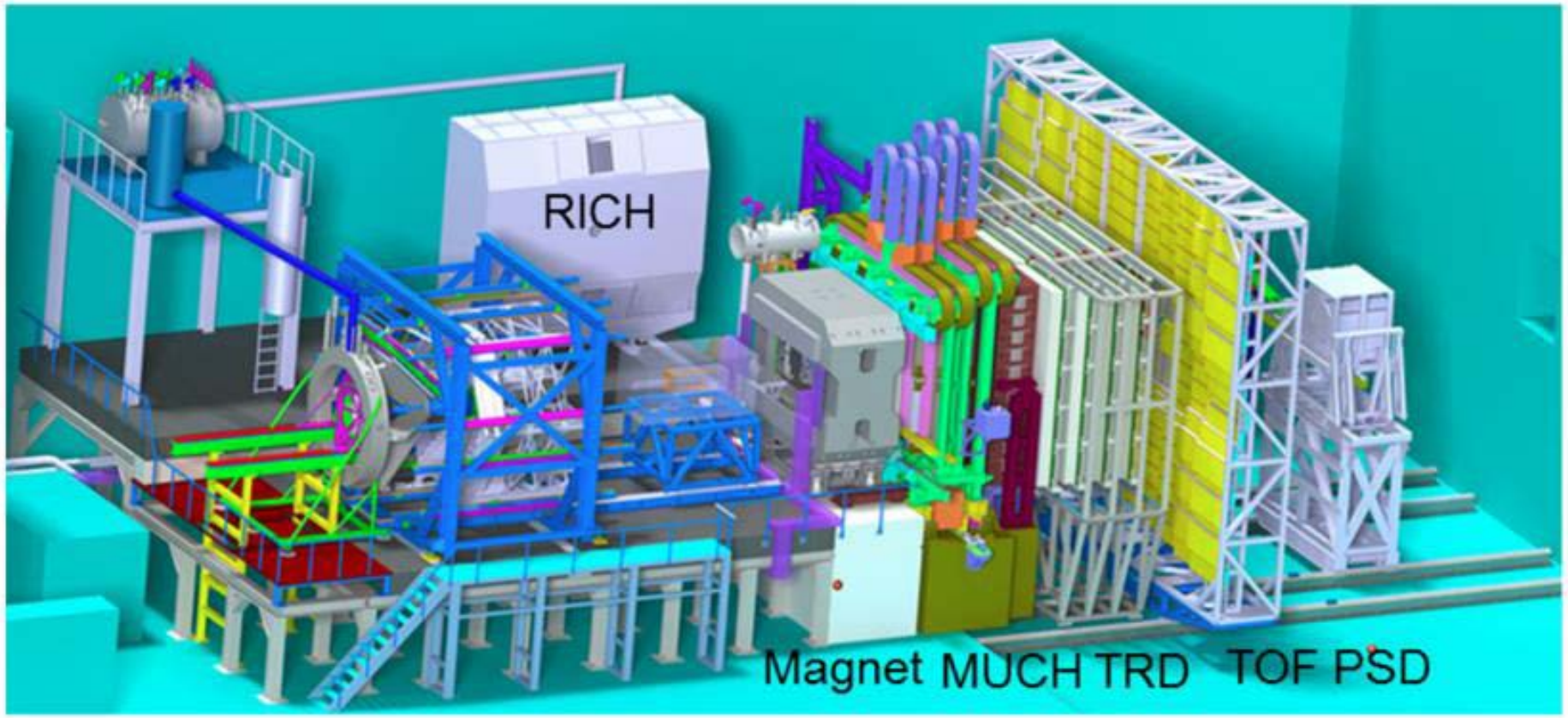
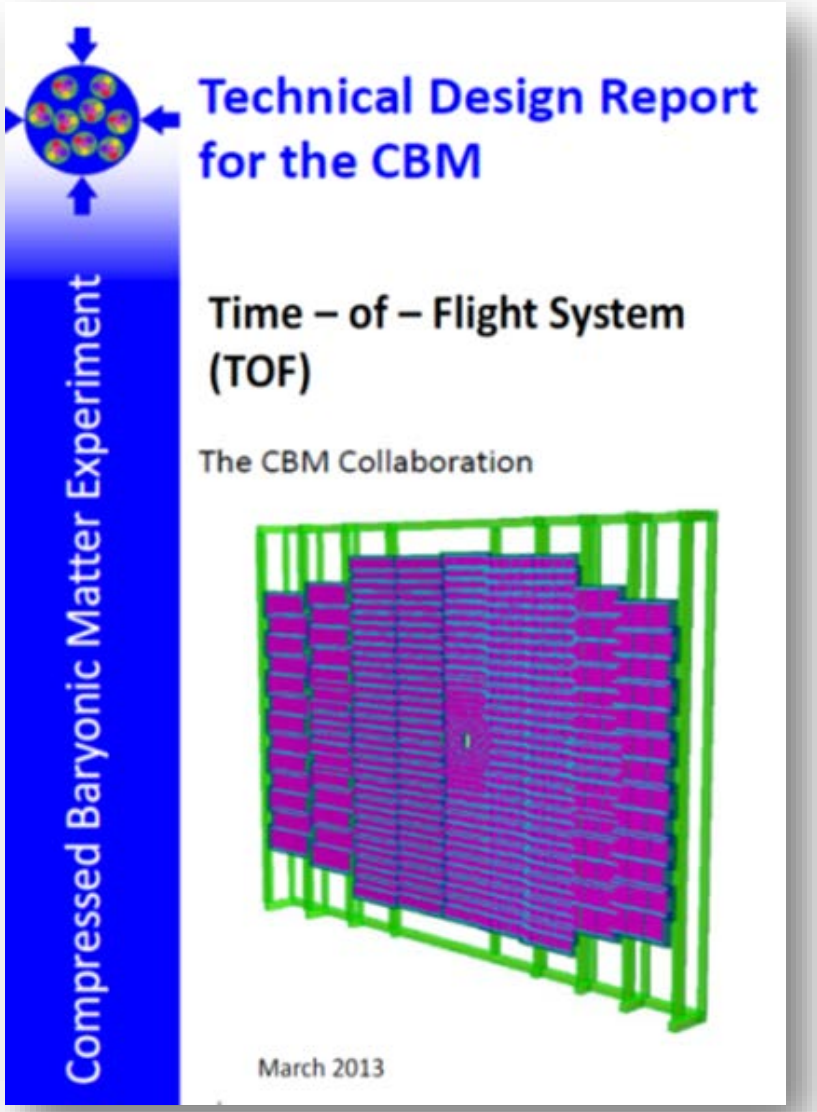
FAIR-CBM实验



CBM整体实验装置

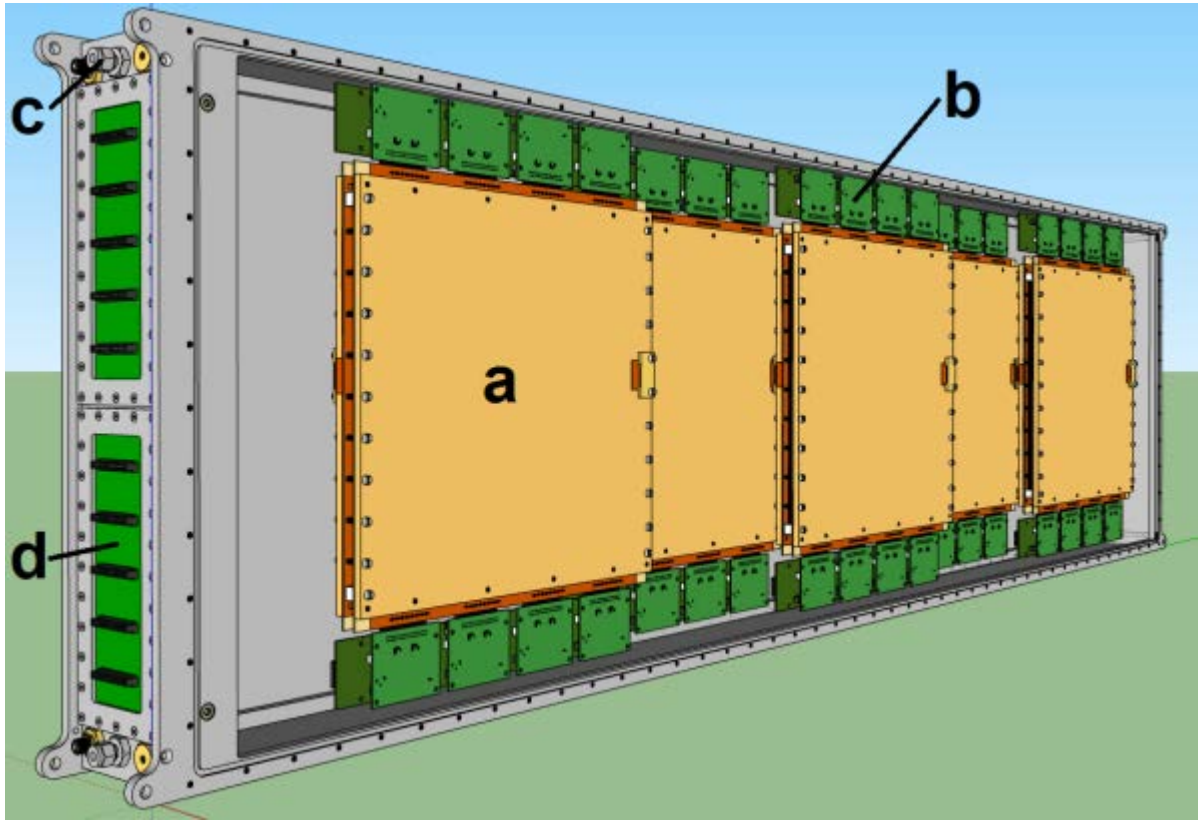
CBM-ToF 性能需求



CBM-ToF的性能要求

- 时间分辨率 ~ 80 ps
- 效率 > 95 %
- 流强≤ 30 kHz/cm2
- 极角范围 2.5° – 25°
- 粒子损失 < 5 %
- 低功耗

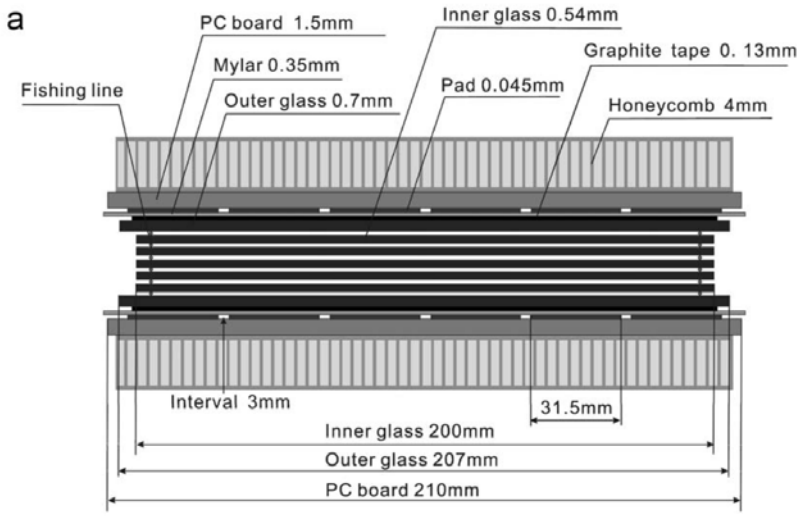
CBM-ToF 模块



	CBM
Active area per detector (cm)	33 x 27.6
Total active area (m^2)	120
Strip width(mm)	7(strip)+3(interval)
Stript length(mm)	270
Gap×thickness(mm)	8 x 0.25
Gas mixtures ($C_2H_2F_4$/ C_4H_{10}/SF_6)	90/5/5
Operating field (kV/cm)	110
Efficiency	97%
Time resolution(ps)	80
Max rate (Hz/cm^2)	**50k**
Glass type	**Low resistive glass**

- CBM-ToF 墙 模块1a
- 模块1a 探测器参数

多气隙阻性板室-Multigap Resistive Plate Chamber



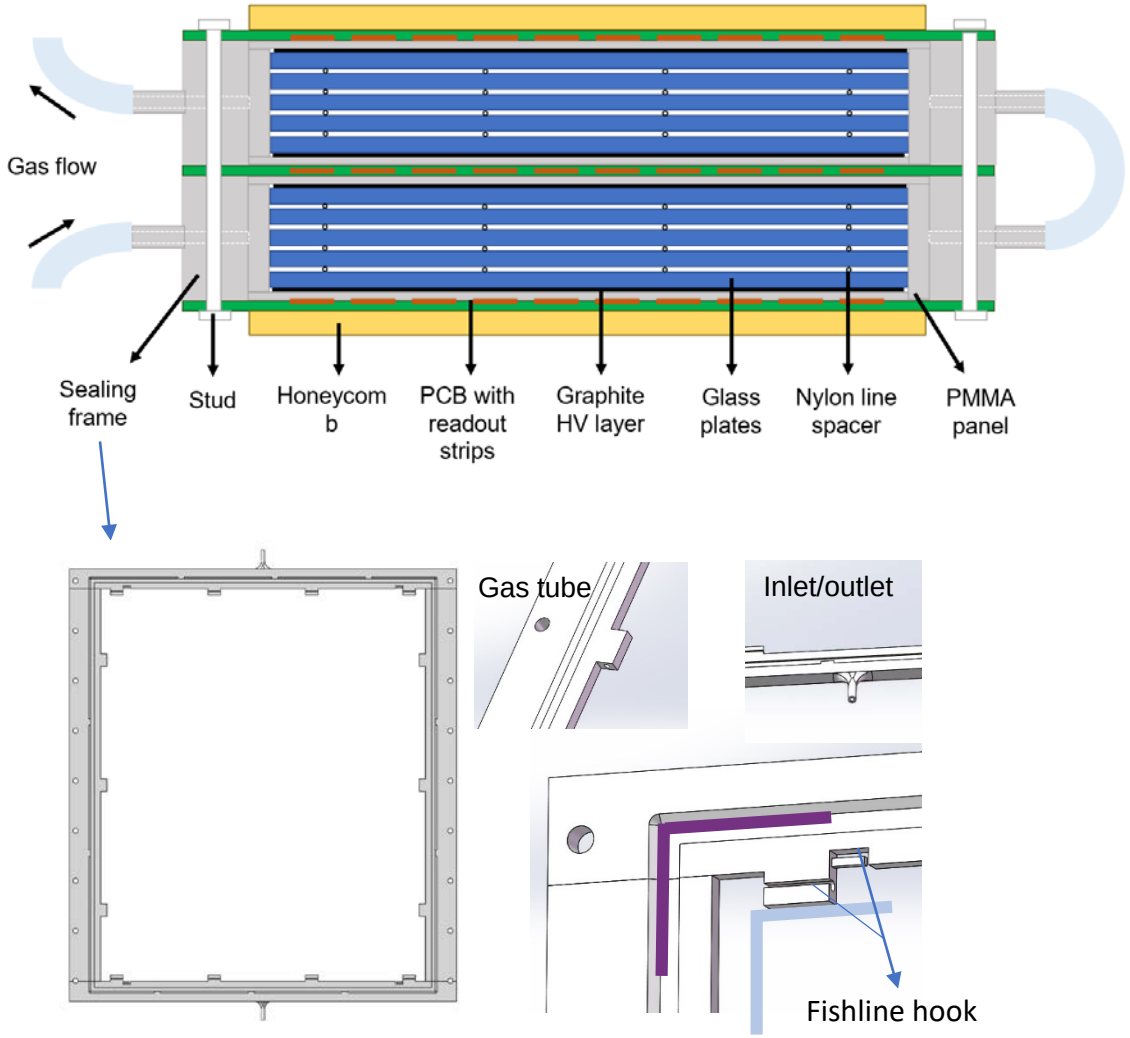
- 窄气隙带来高时间分辨率
- 足够的气隙宽度带来足够的探测效率

MRPC被广泛应用于高能物理实验中的飞行时间（ToF）系统

					In construction	Proposed
	STAR	ALICE	FOPI	BESIII	CBM	SoLID
Active area per detector (cm)	22 x 8.4	120 x 13	90 x 4.6	0.5x(9.2+14.8)x32.8	33 x 27.6	--
Total active area (m^2)	50	141	5	1.33	120	10
Pad size (cm)	6.3 x 3.1	3.7 x 2.5	90 x 0.3	(9.1~14.1) x 2.4	27 x 1.0	(16~28) x 2.5
Gap×thickness(mm)	6 x 0.22	10 x 0.25	6 x 0.3	12 x 0.22	10 x 0.25	10 x 0.25
Gas mixtures ($C_2H_2F_4$/C_4H_{10}/SF_6)	95/5/0	90/5/5	85/5/10	90/5/5	90/5/5	90/5/5
Operating field (kV/cm)	107	96	110	109	110	106
Efficiency	95-97%	99.9%	97±3%	99%	97%	98%
Time resolution(ps)	60	40	73±5	60	80	**20 ps**
Max rate (Hz/cm^2)	10	50	50	50	**50k**	**10k**

MRPC探测器同时拥有**高探测效率**和**高时间分辨率**的优点.

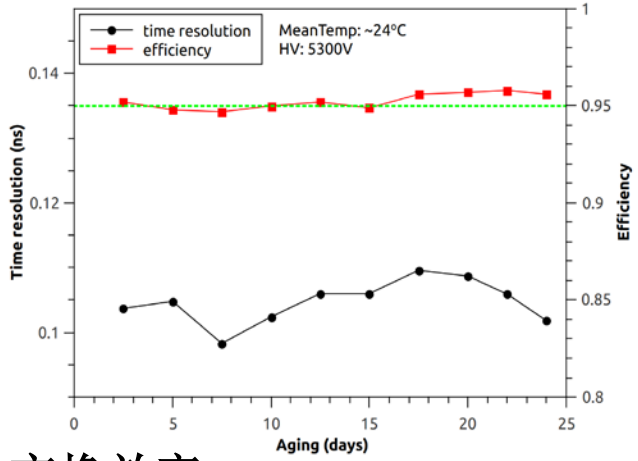
密封型多气隙阻性板室-Sealed MRPC



密封框由3D打印制成，上下两测由玻璃密封。

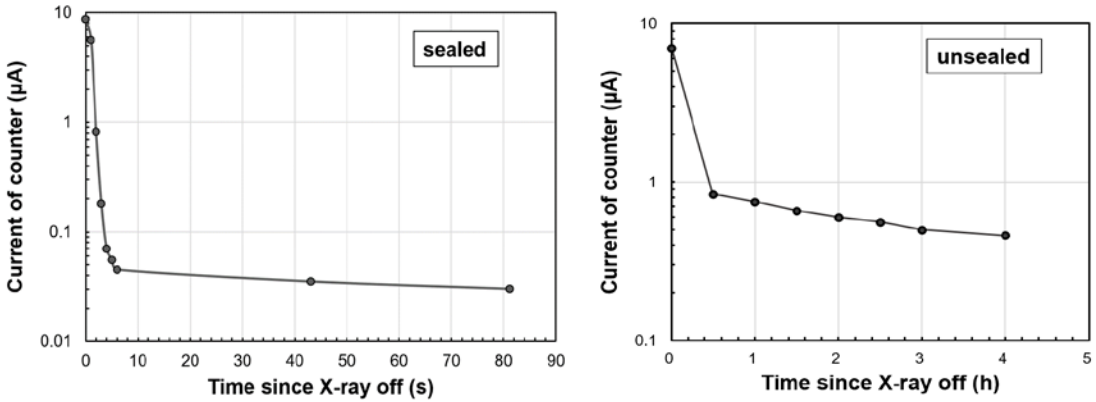
- 优势：

1. **节约气体:** 可以在气体流量低于 10 sccm/m²的情况下稳定工作



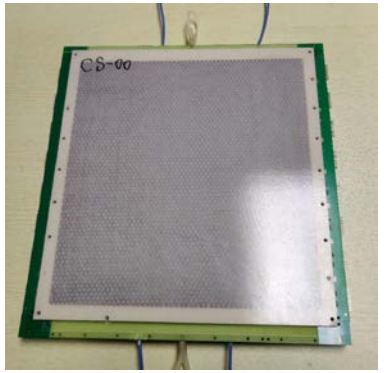
2. **高气体交换效率**

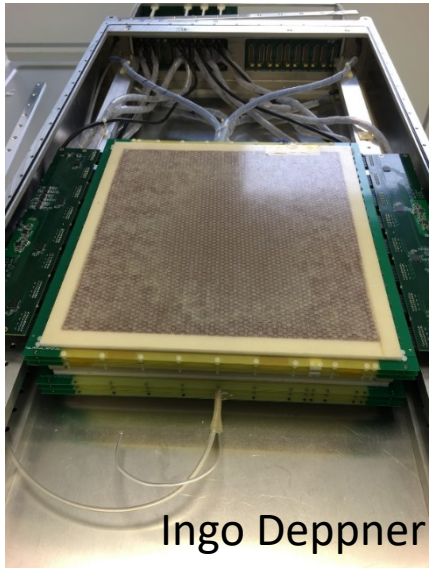
- 减少X射线实验中的气体交换等待时间
- 在高流强环境下带来更好的工作电流性能

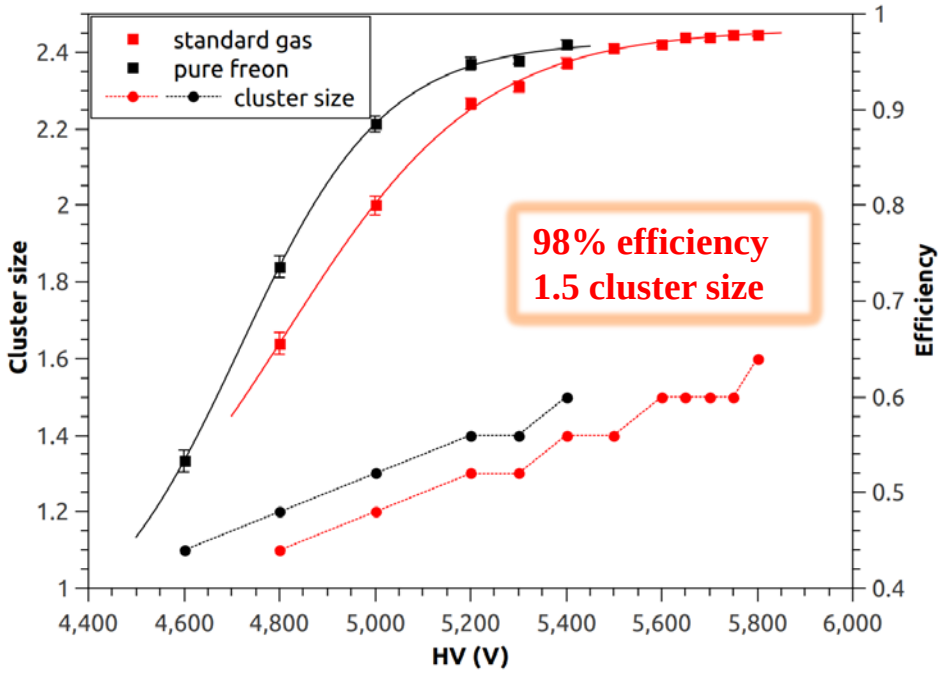


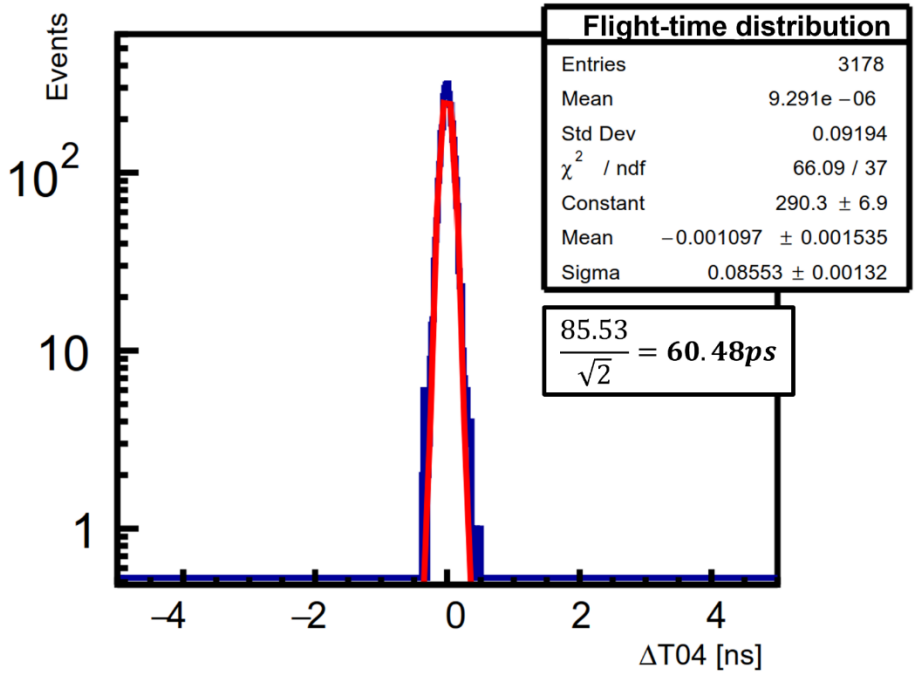
为CBM-ToF制造的密封型MRPC

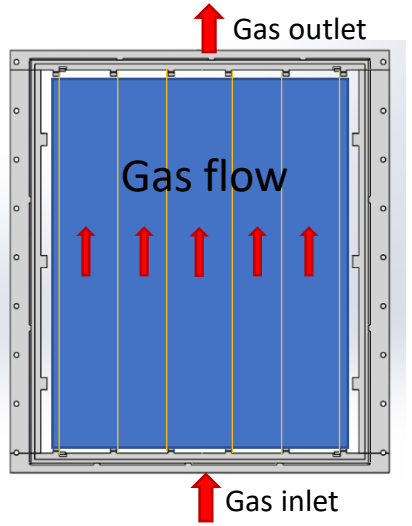
- 与非密封型MRPC相对比，拥有相同的尺寸与有效面积
- 保持了高时间分辨率与探测效率







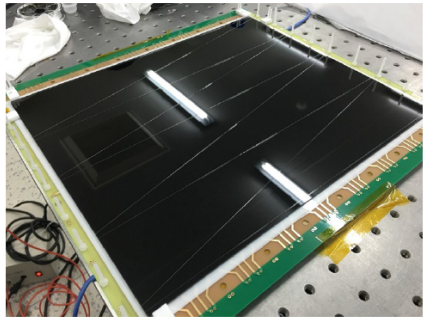


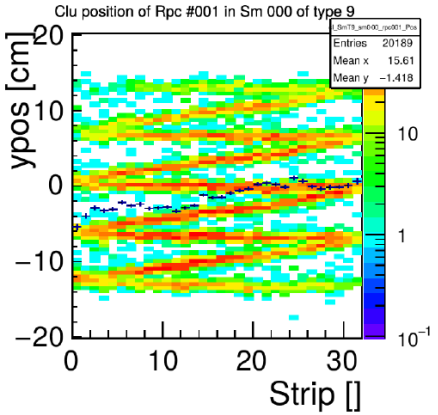


鱼线MRPC上的“爬电效应”

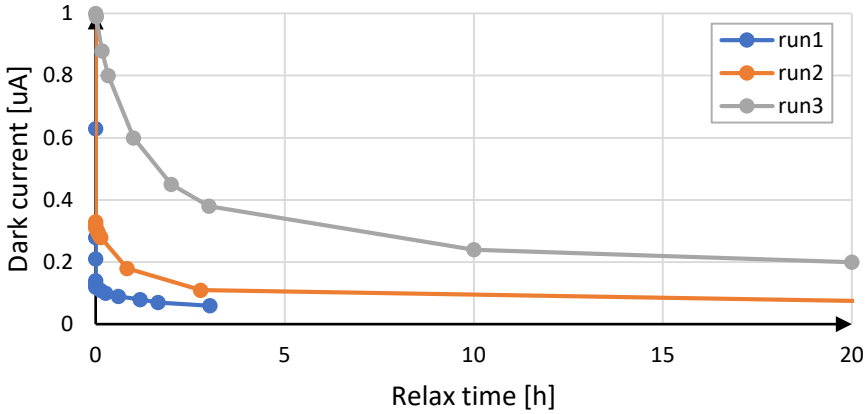
在鱼线间隔所在的区域会发生**连续放电**

- 高噪声计数率@ Ingo Deppner

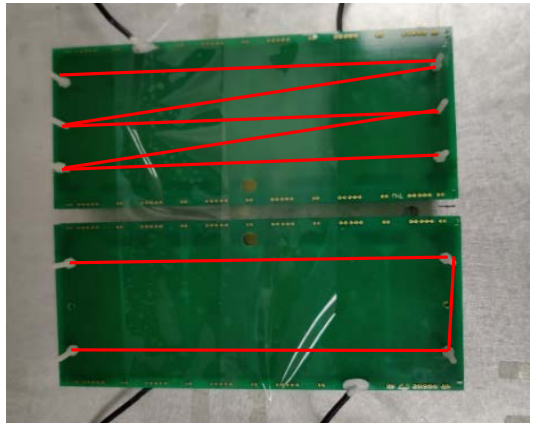




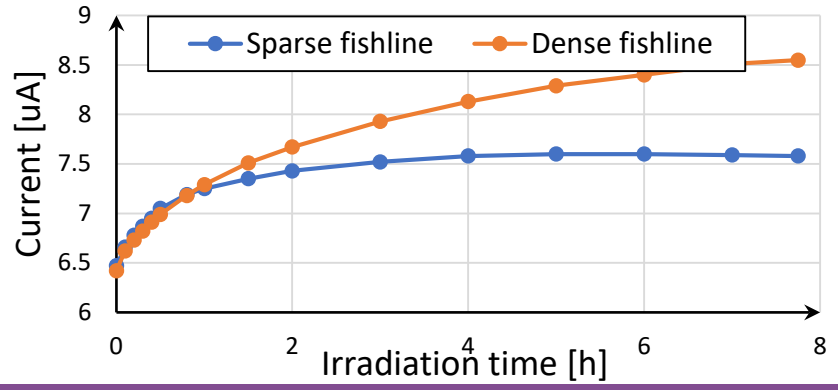
- 高流强照射（X射线）会产生长期效应



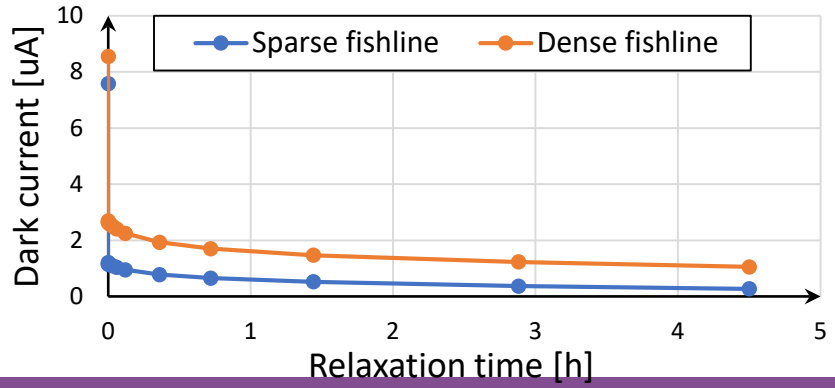
鱼线区域面积越大, 高流强下的电流表现越差。



- 稀疏的鱼线-电流更早稳定

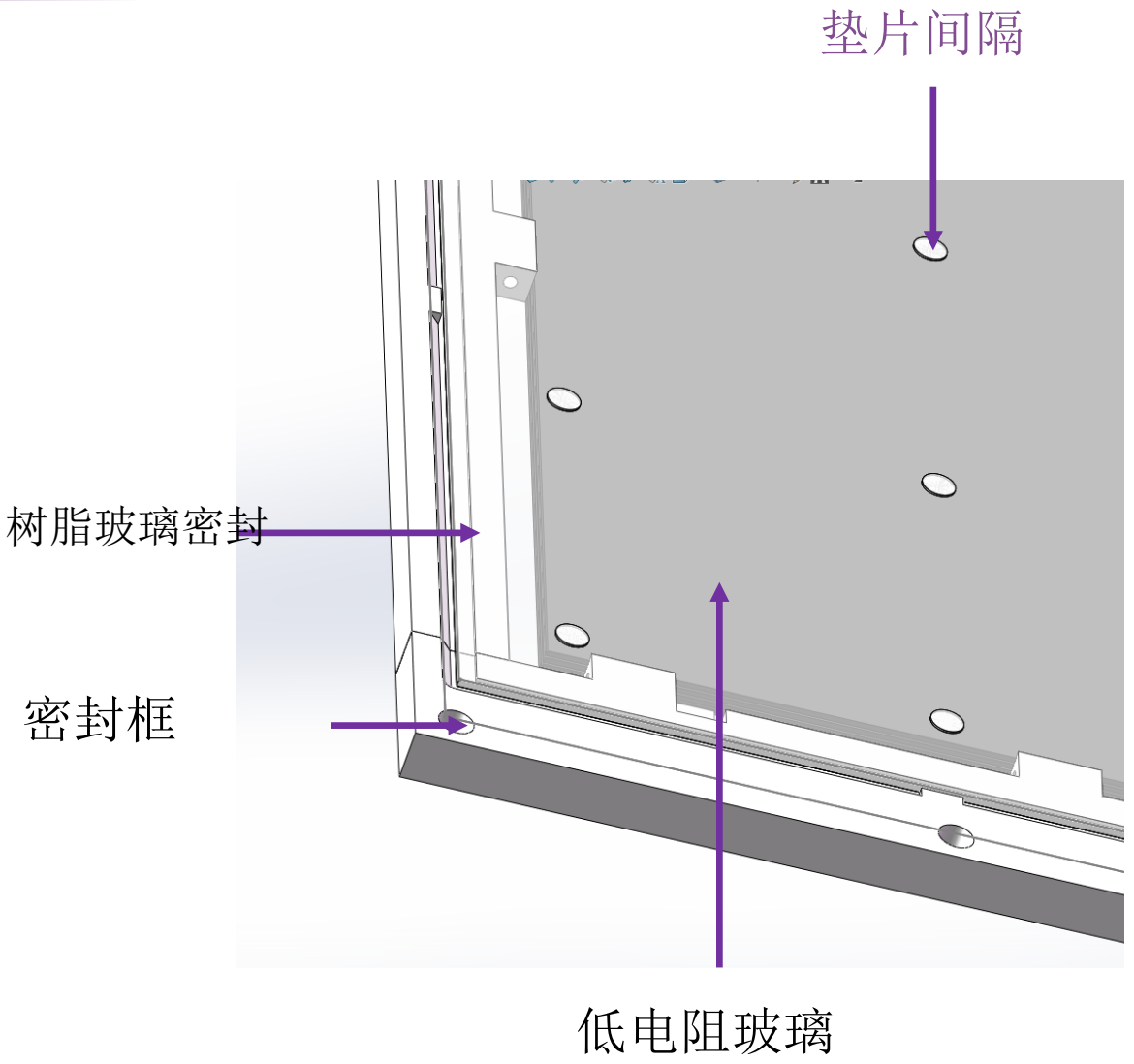


- 稀疏的鱼线-暗电流更小.



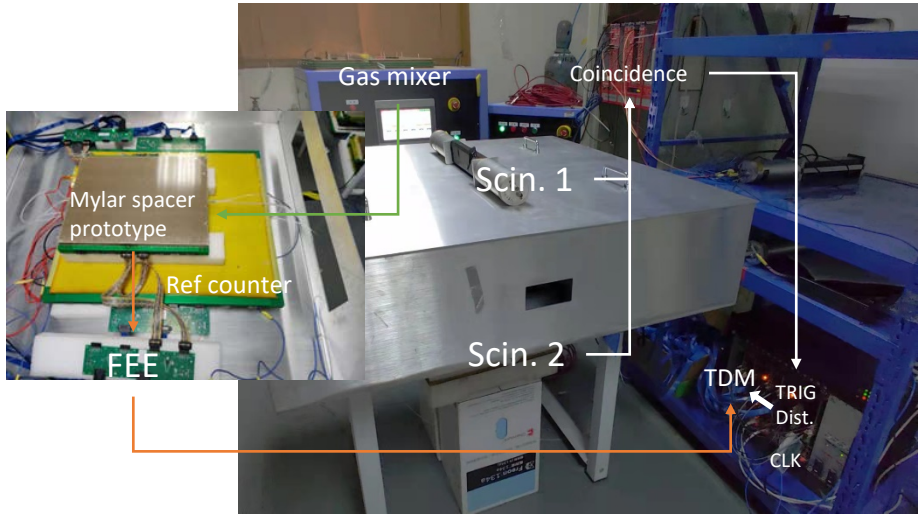
垫片式MRPC

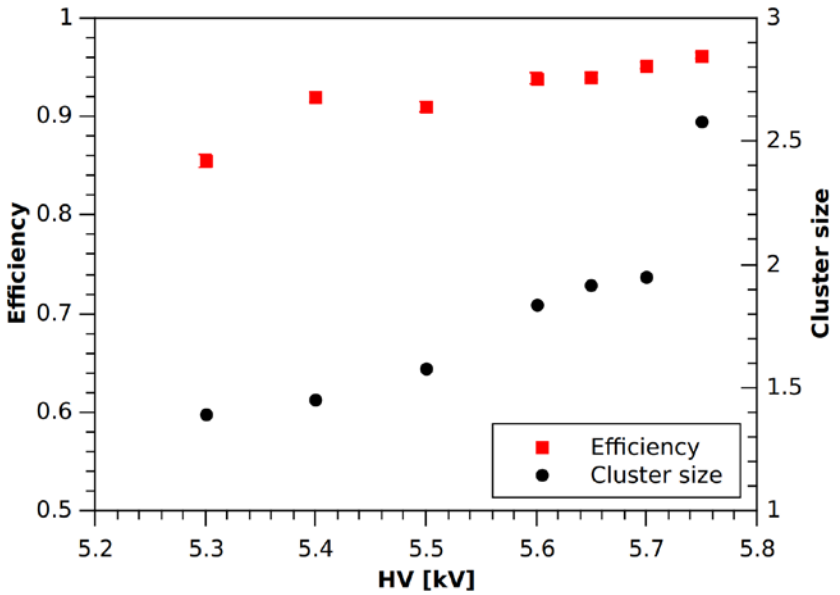
Sealed MRPC2 parameters	
Active area per detector (mm)	330 x 276
Stacks × gaps	2 x 4
Gap thickness(mm)	0.25
Strip size (cm)	27 x 1.0
Gap thickness(mm)	0.25
Operating field (kV/cm)	110
Round pad spacer parameters	
Dimensions (diameter)	Φ =4mm
Thickness(mm)	0.25
Number (horizontal × vertical)	8 x 7
Horizontal intervals(mm)	45
Vertical intervals (mm)	46.3

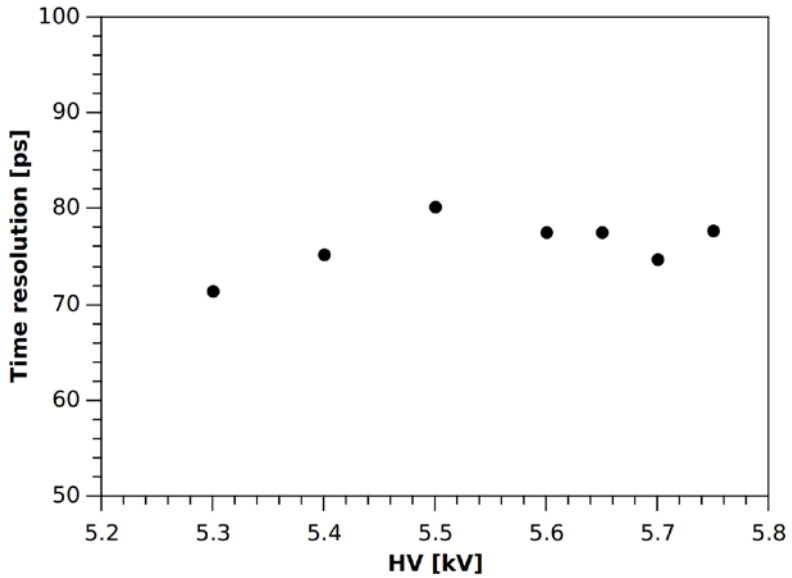


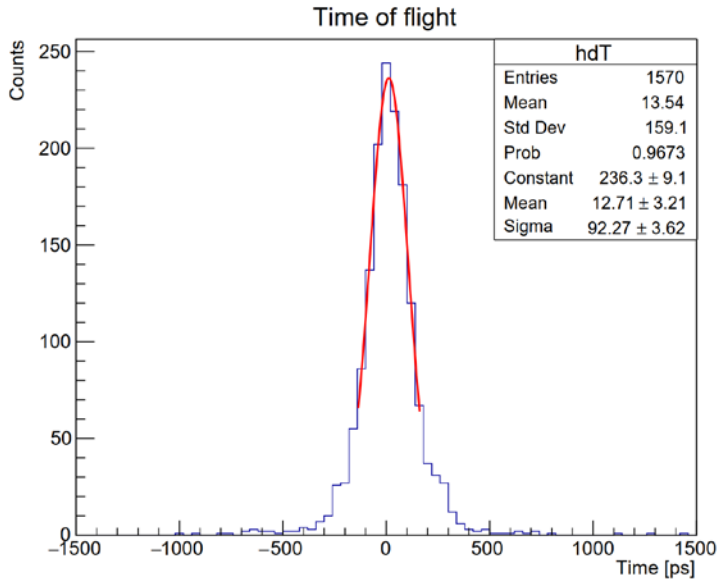
宇宙线测试结果-垫片式MRPC

- NINO-based FEE: 阈值150mV
- FPGA-TDM
- 进行了基于工作场强的扫描
- 场强范围108-114 kV/cm
- 暗电流: 小于50 nA
- **95%** 效率， 时间分辨率**71 ps**





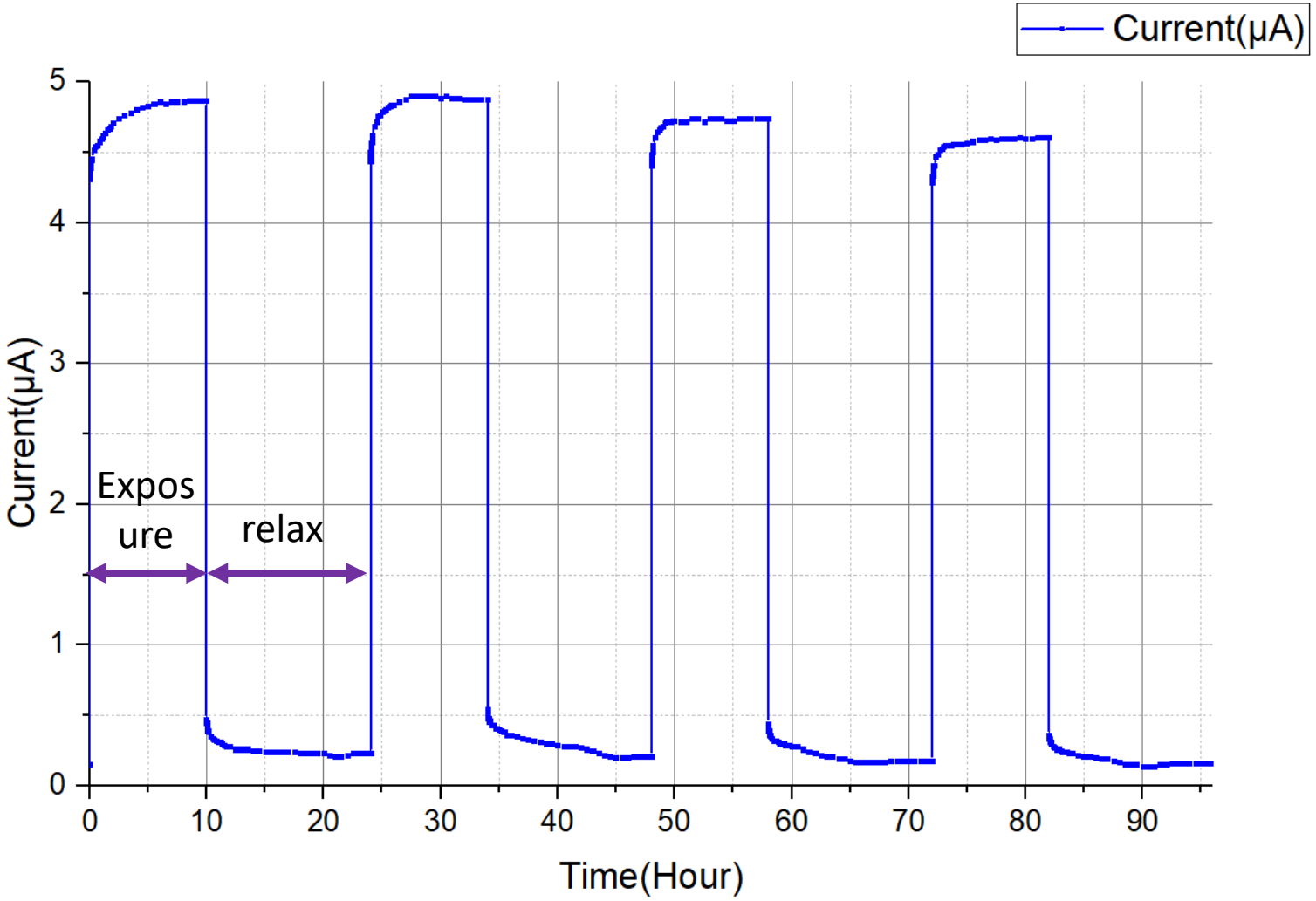




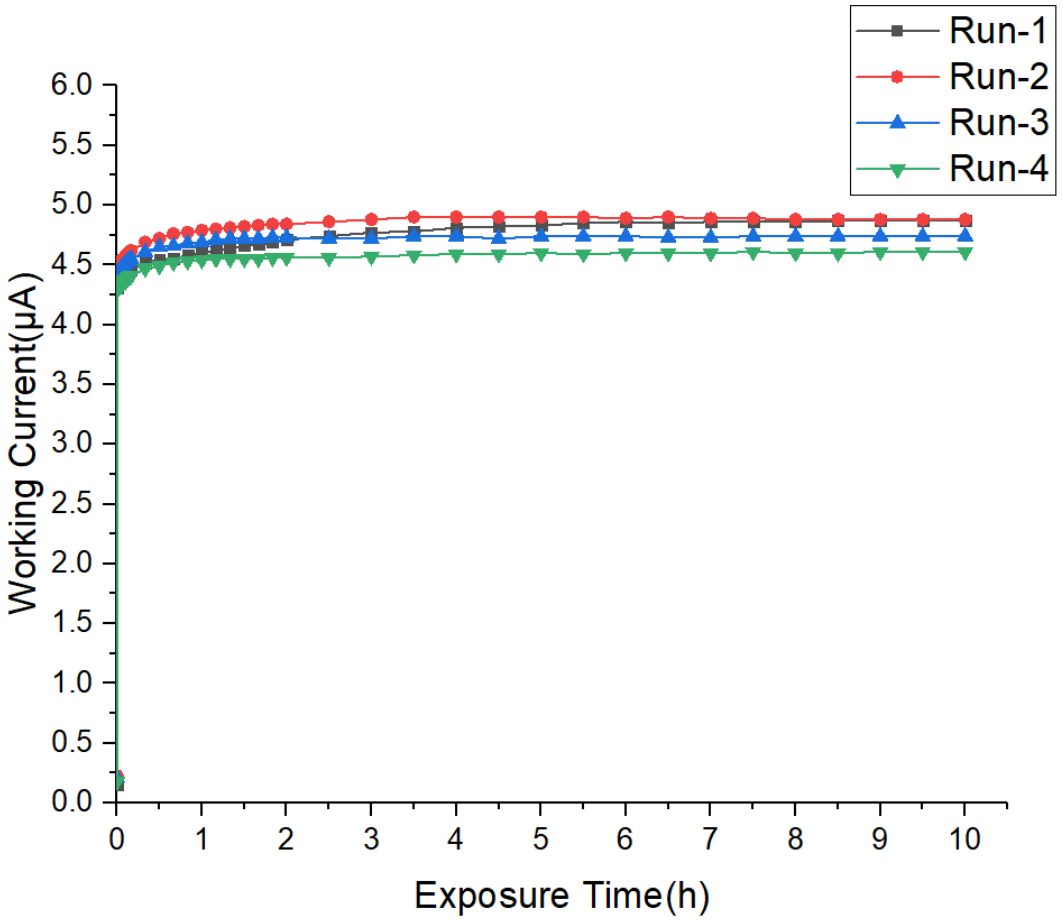
X射线结果- 垫片式密封型MRPC

长时间照射测试:

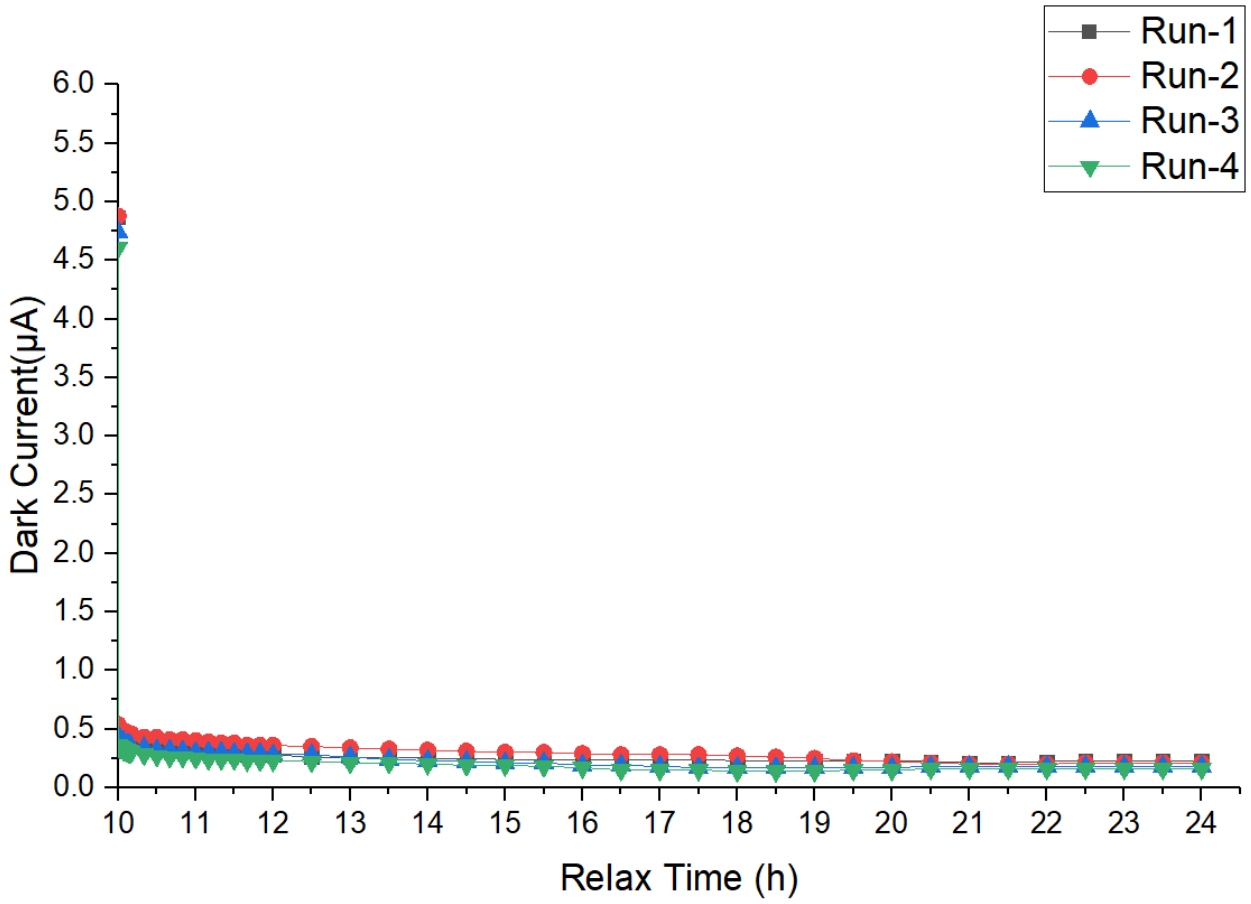
- X射线管: 45kV / 0.1mA
- 共4轮
- X射线照射10小时
- X射线停止14小时
- 流强 3KHz/cm^2



X射线结果- 垫片式密封型MRPC

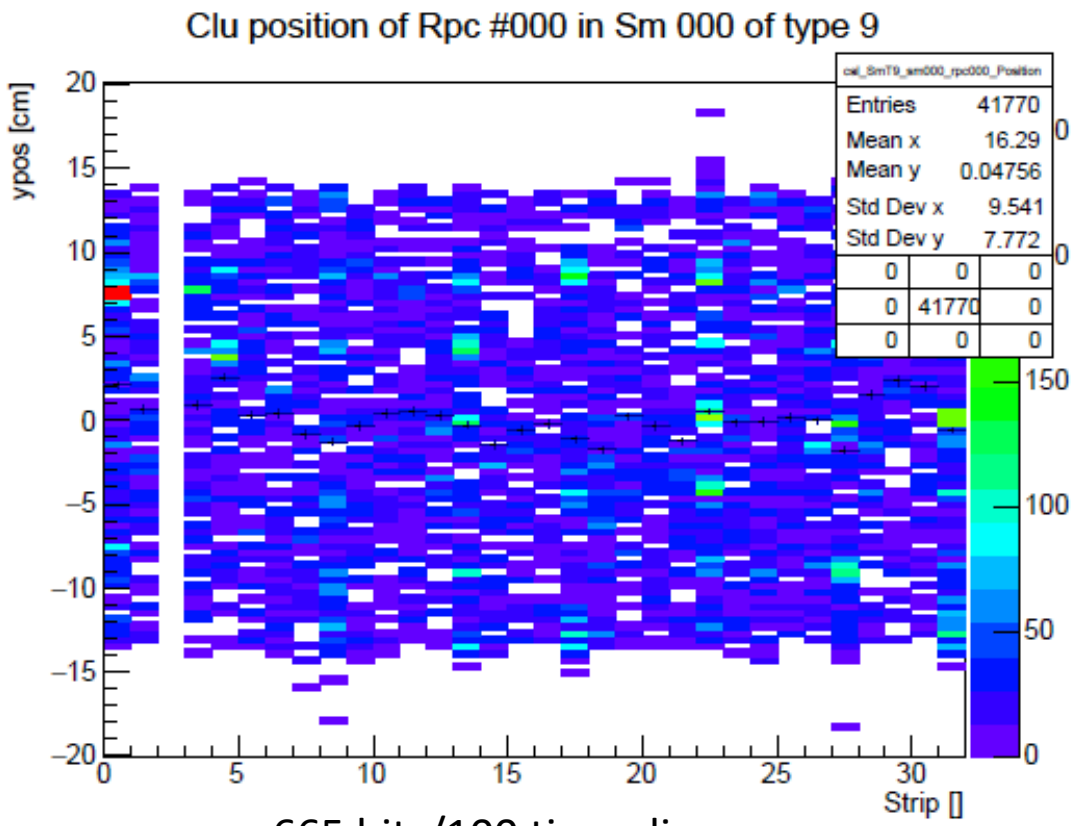


10小时X射线照射-工作电流@3 kHz/cm^2



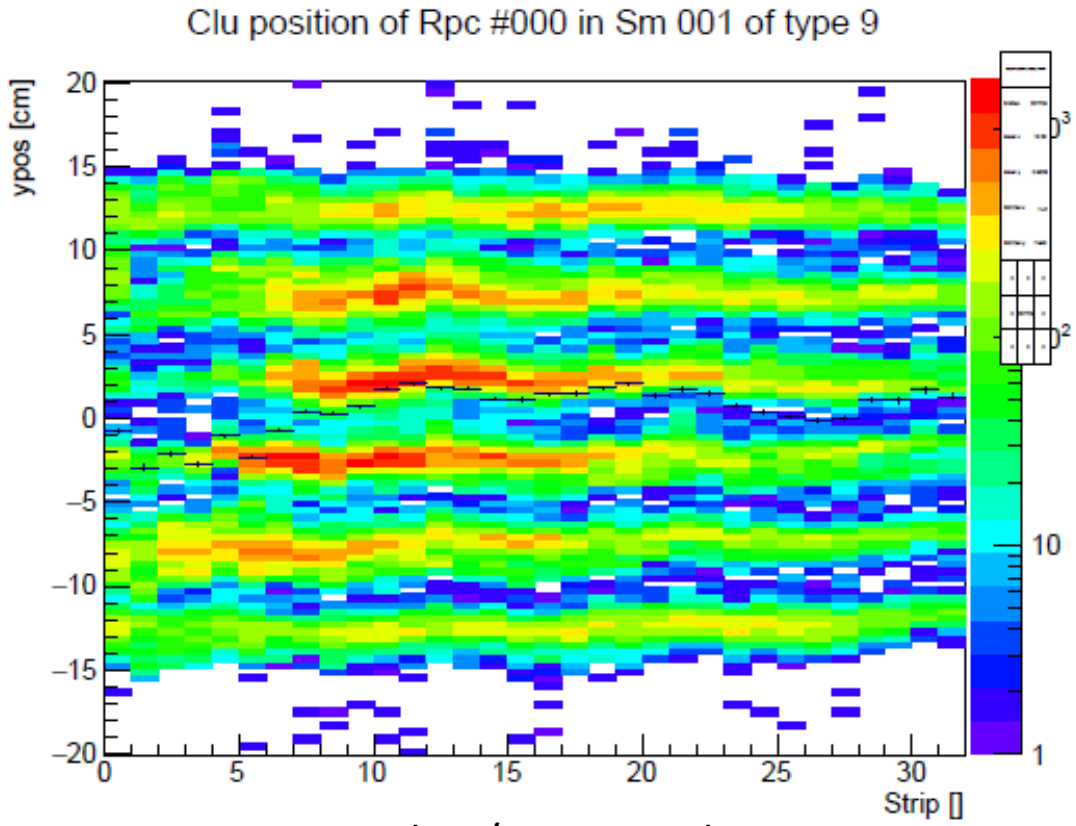
14小时恢复

垫片式密封型MRPC的噪声情况@Ingo Deppner



665 hits/100 time slices

垫片式MRPC2

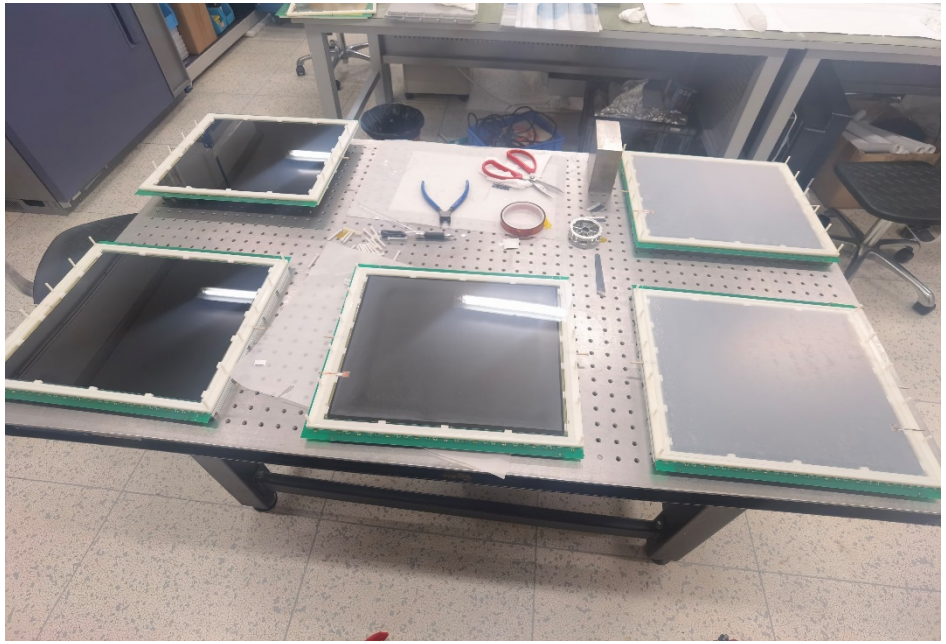


18646 hits/100 time slices

鱼线式 MRPC2

小批量生产情况

- 已经制造20个密封型MRPC，并已经运抵CBM项目组进行测试。
- 其中包括15个密封型鱼线MRPC与5个密封型垫片MRPC。



生产过程

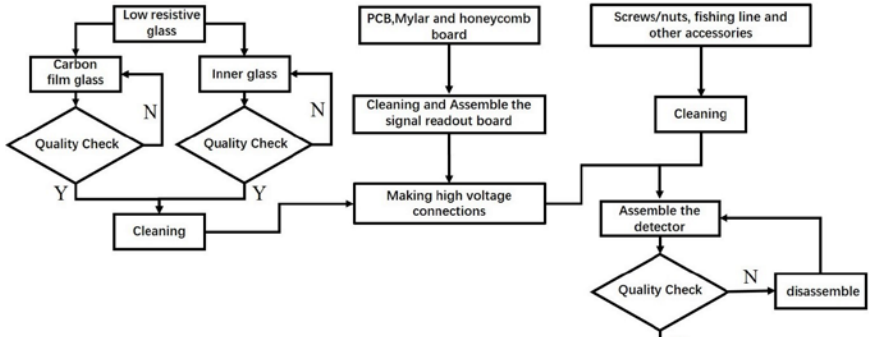
气密性及高压测试

大批量生产准备

大批量生产环境准备

- 喷涂机-制造提供高压的碳膜玻璃
- 水槽-清洗玻璃
- 位于威视密云基地的100k洁净间-组装
- .etc

生产流程



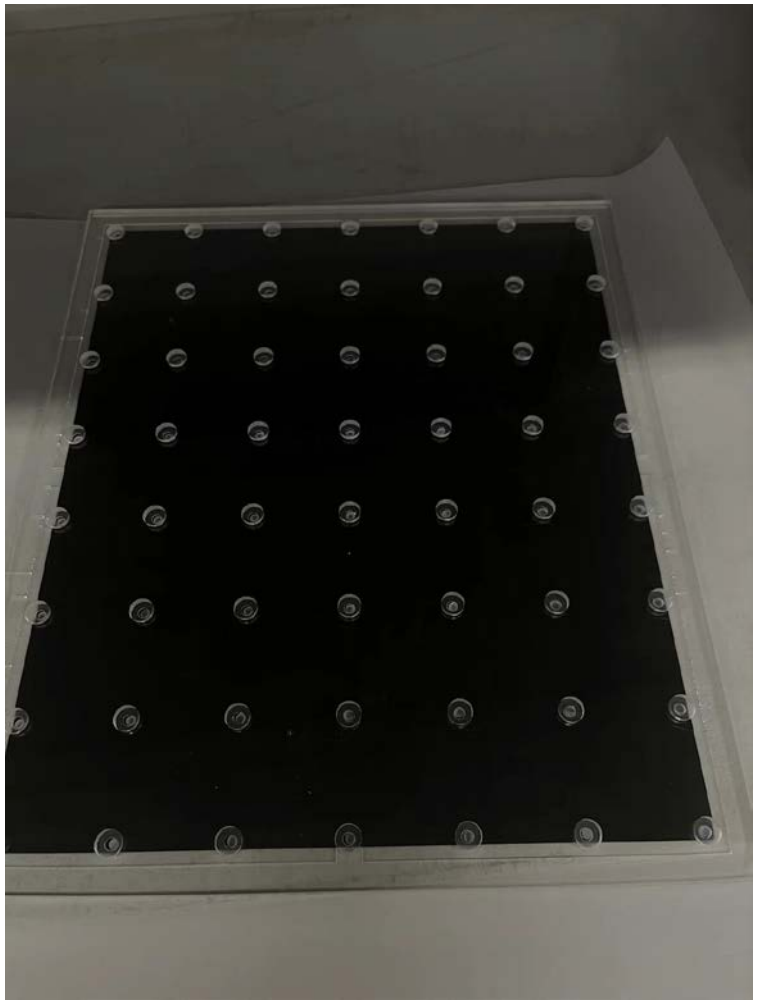
QA and QC

- 气密性测试
- 高压测试
- .etc

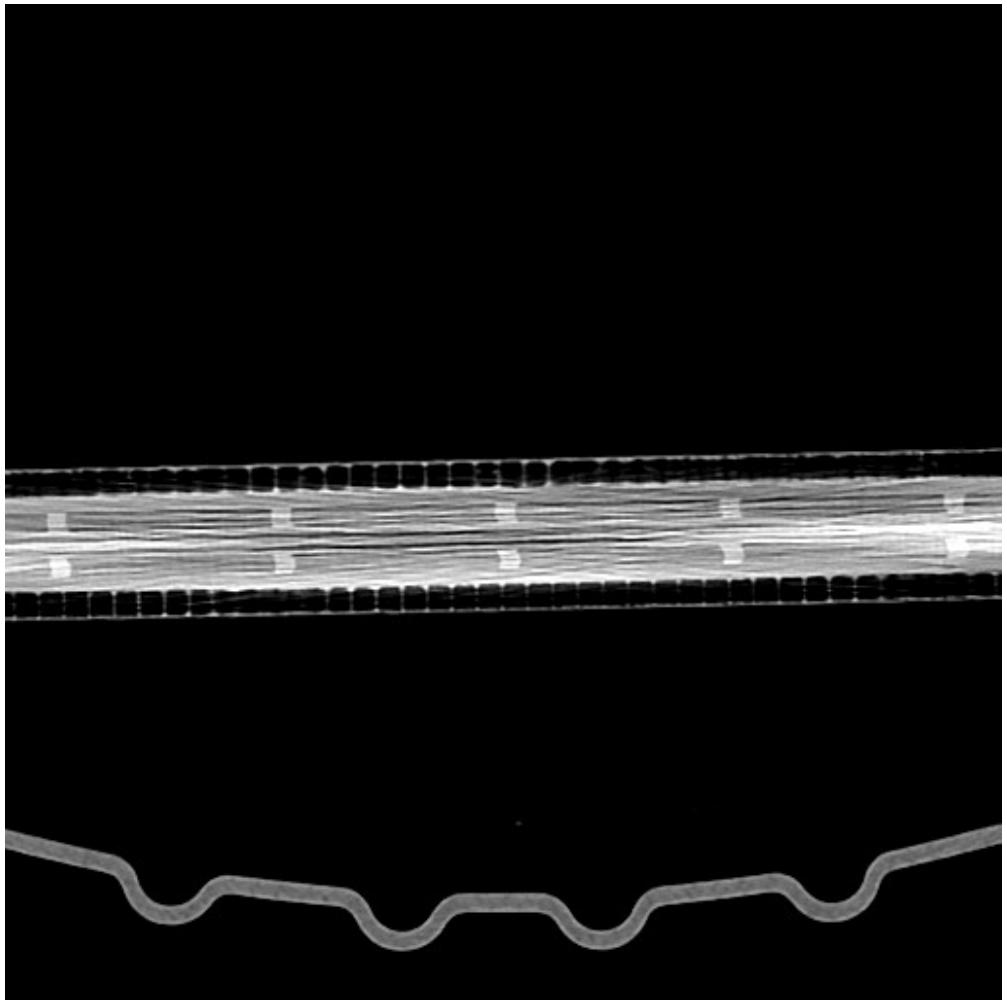
大批量生产准备-密封型垫片式MRPC

- 冲压机-用以制造垫片

- 垫片式MRPC粘贴模具



- CT扫描图像



总结

- **为FAIR-CBM-ToF设计了可应用于高计数率飞行时间测量的密封型多气隙阻性板室探测器，探测器使用低电阻玻璃来提高高流强下的探测效率。**

- **垫片式MRPC在实验中表现了更好的电流性能和噪声性能:**
  - 在X射线实验中表现了优秀的电流性能
  - 在mCBM的实验测试中表现了更优秀的噪声性能

大规模生产准备

- 生产环境准备
- 制造工艺流程
- 质量控制与检查

大规模生产准备-垫片式MRPC:

- 冲压机
- 粘贴模具
- 基于CT的垫片移位检测

谢谢大家!

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