清華大學
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Possible MRPC detector for CEPC-TOF

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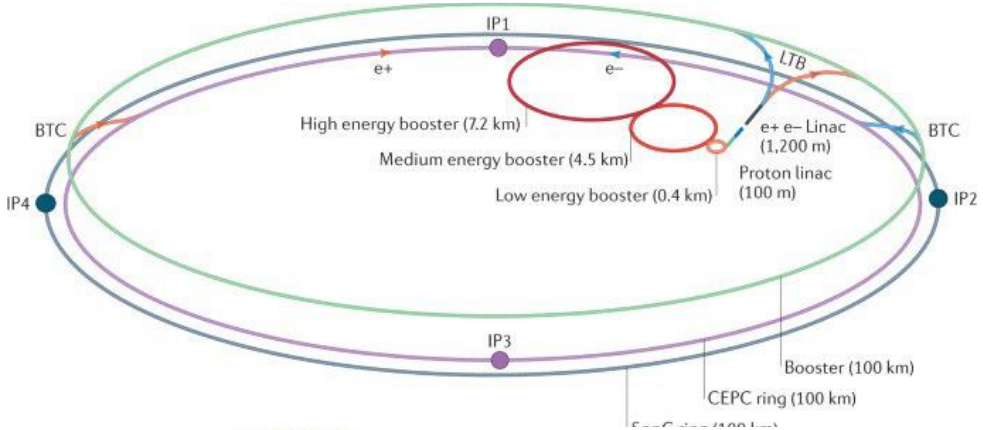
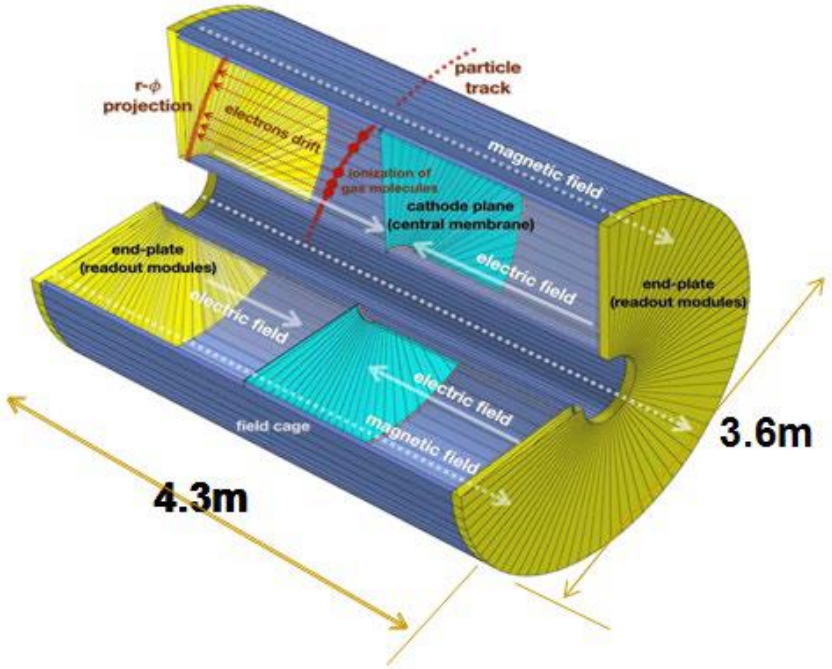
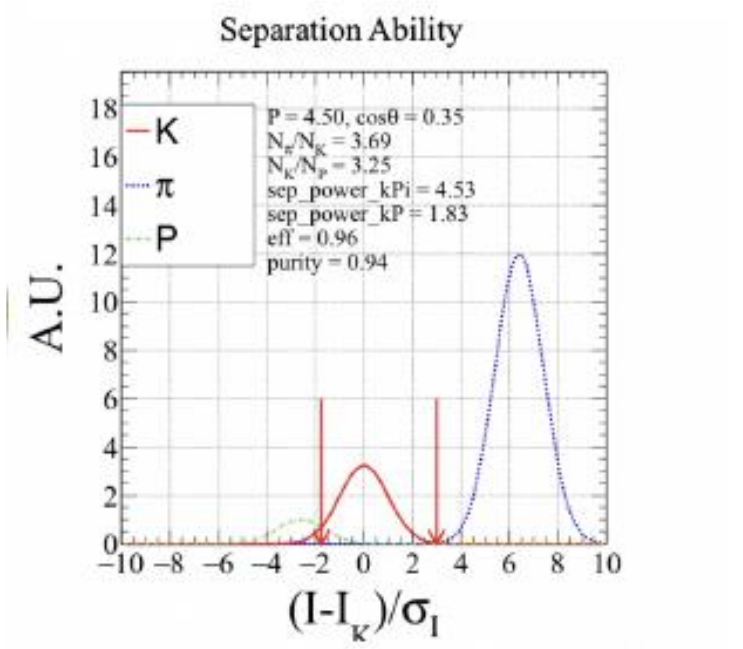
PID of CEPC





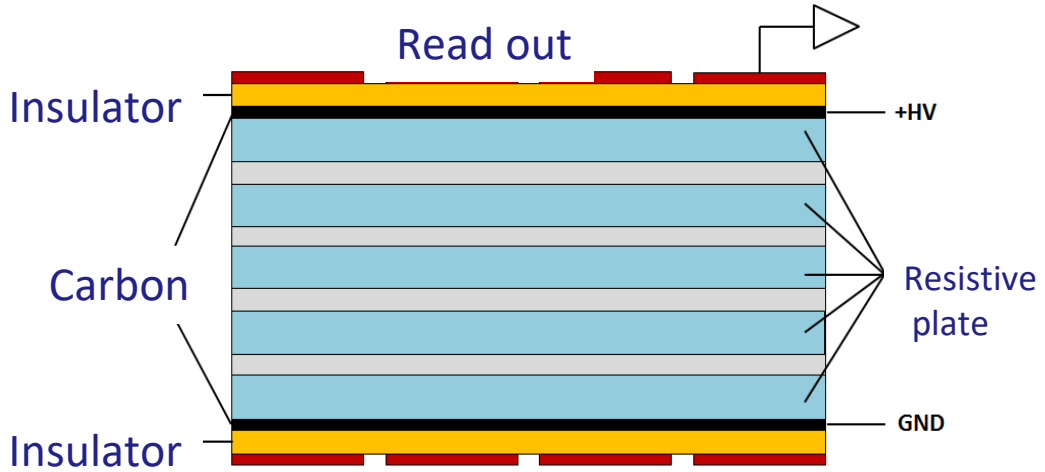


Geant4 simulation:

- TPC resolution: <2.5%
- TOF: <50ps
- PID of K: >98%

From Manqi's summary @ 2022 CEPC workshop

A good choice-MRPC



MRPC structure

MRPC application：

1. Application in nuclear physics experiments
2. Application in industry （Muon tomography)
3. Application in medicine （TOF-PET）

Standard parameters:

Resistivity of glass: ~$10^{12}\ \Omega.\mathrm{cm}$

Working gas: 90%Freon+5%iso-butane+5% SF6

Time resolution <100ps

Efficiency >95%

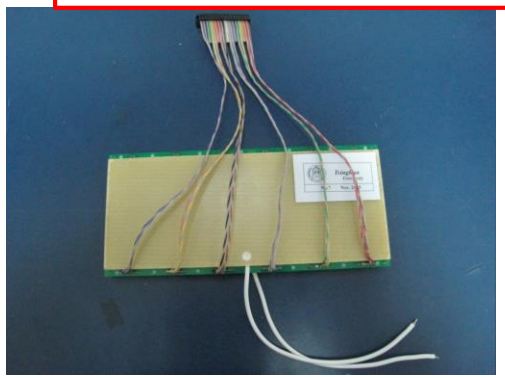
Charge: a few PC

Dark current: a few nA

Noise ~1Hz/cm^2

Rate <100 Hz/cm^2

Large area, low cost



MRPC in TOF system

	ALICE	STAR	FOPI	BESIII	CBM	SoLID
Active area per detector (cm)	120 x 13	22 x 8.4	90 x 4.6	0.5x(9.2+14.8)x32.8	33 x 27.6	--
Total active area (m^2)	141	50	5	1.33	120	10
Pad size (cm)	3.7 x 2.5	6.3 x 3.1	90 x 0.3	(9.1~14.1) x 2.4	27 x 1.0	(16~28) x 2.5
Gap×thickness(mm)	10 x 0.25	6 x 0.22	6 x 0.3	12 x 0.22	10 x 0.25	32 x 0.128
Gas mixtures ($C_2H_2F_4$/ C_4H_{10}/SF_6)	90/5/5	95/5/0	85/5/10	90/5/5	90/5/5	90/5/5
Operating field (kV/cm)	96	107	110	109	110	150
Efficiency	99.9%	95-97%	97±3%	99%	97%	98%
Time resolution(ps)	40	60	73±5	60	60	**20 ps**
Max rate (Hz/cm^2)	50	10	50	50	**30k**	**20k**

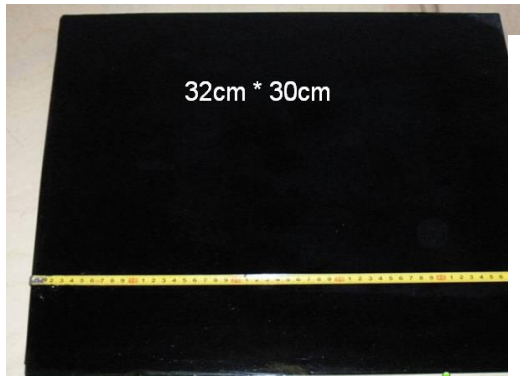
higher **counting rate** and **time precision**.

Low resistive glass for high rate detector

- low-resistive glass control the voltage drop (efficiency loss) when incident flux goes up by Decrease the resistivity of the electrodes

$$V_{gap} = V_{ap} - \bar{V}_{drop}$$

$$\bar{V}_{drop} = \bar{I}R = \bar{q}\Phi\rho d$$

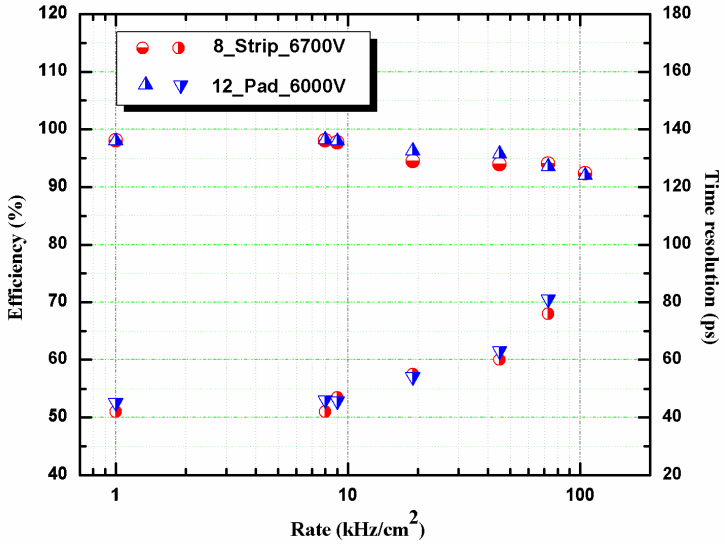


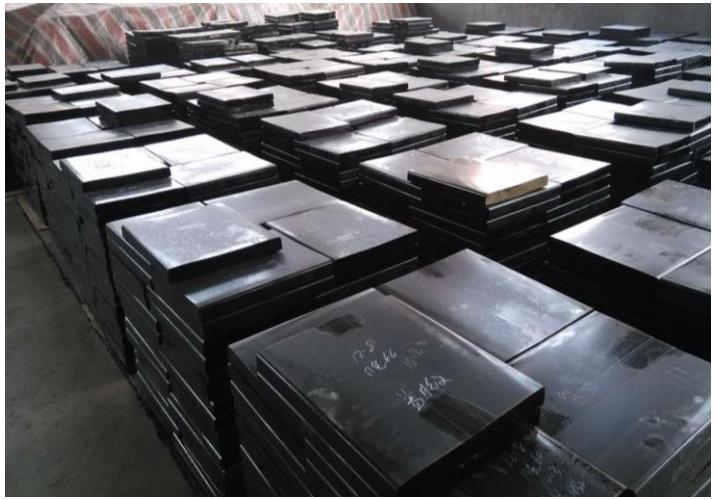
Specifications of low resistive glass

Maximal dimension	32cm × 30cm
Bulk resistivity	10^{10} Ωcm
Standard thickness	0.7, 1.1mm
Thickness uniformity	20 μm
Surface roughness	< 10nm
Dielectric constant	7.5 - 9.5
DC measurement	Ohmic bebavior stable up to 1 C/cm^2

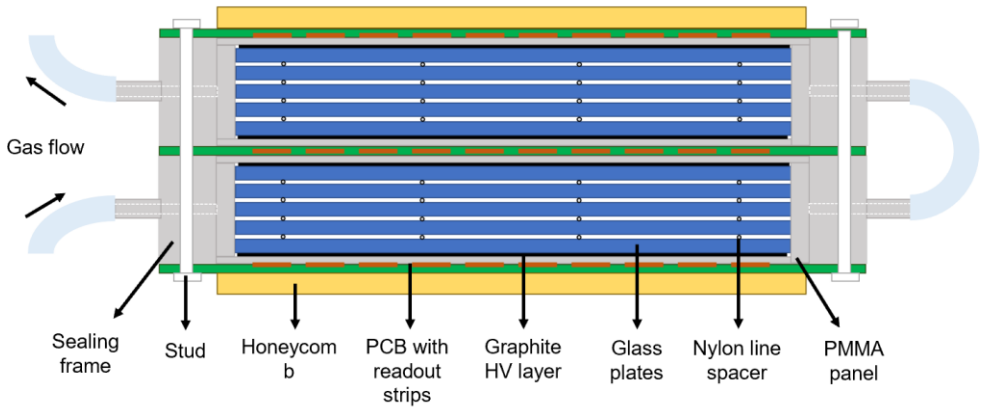
- Low-resistive glass has been operating at FAIR-Phase 0 programs like STAR-eTOF and mCBM
- It will be applied in CBM-ToF Wall
- Beam test result:

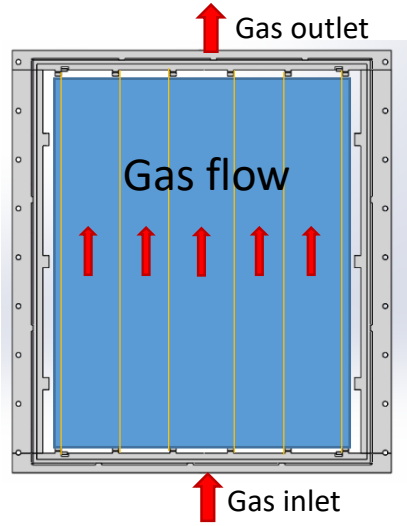
93%, 80ps ,70kHz/cm^2





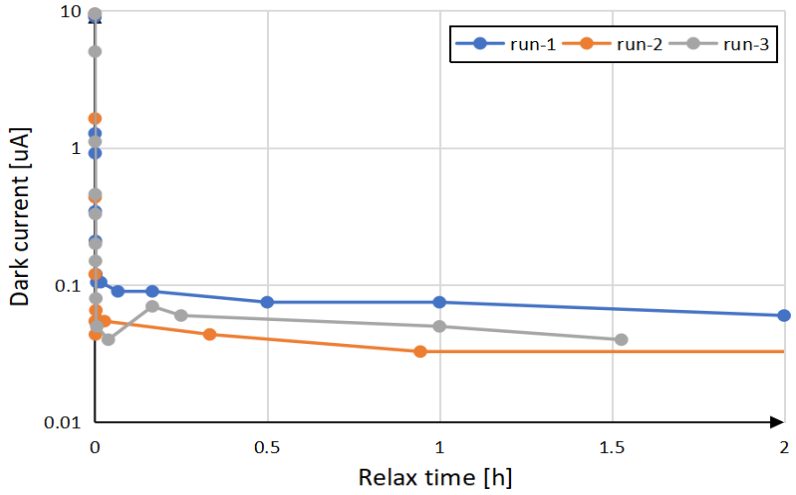
Sealed pad spacer MRPC for CBM-TOF



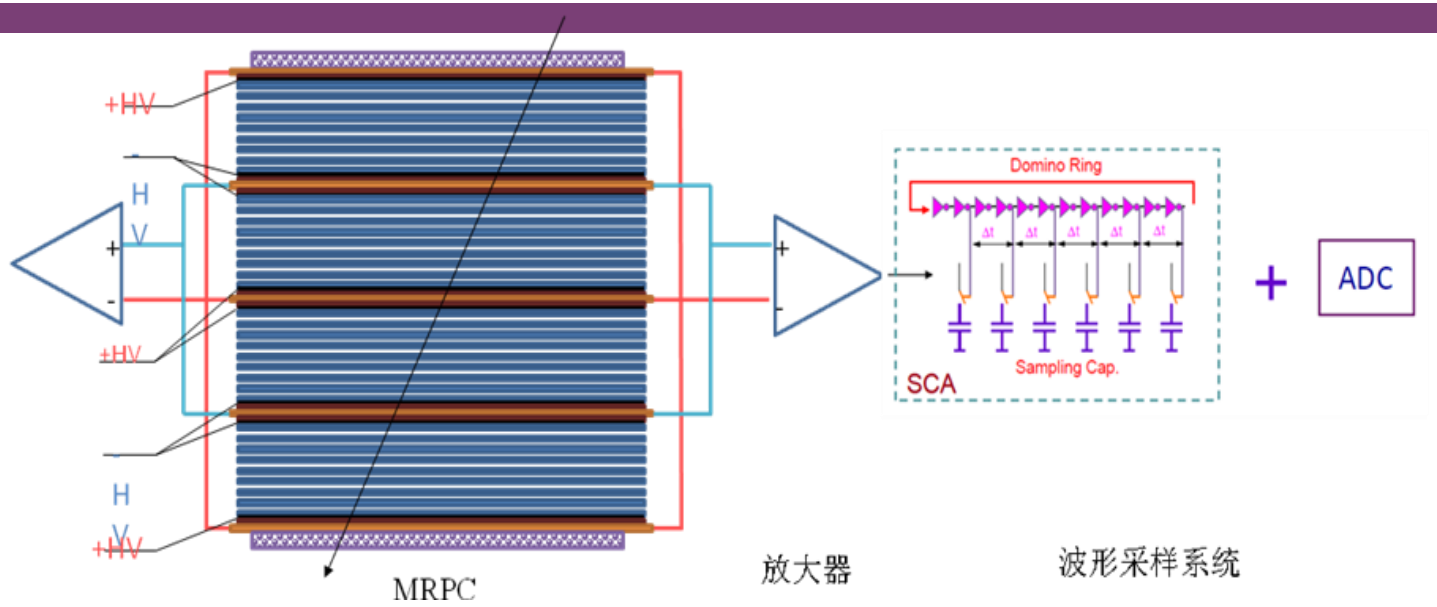


Sealed pad spacer MRPC

- Speed up gas exchange and can reduce to 1sccm/m^2 flush rate at cosmic experiment!
- Prevent creepage on fishing line at high rate (>7kHz/cm^2)
- Save working gas and environmentally friendly.



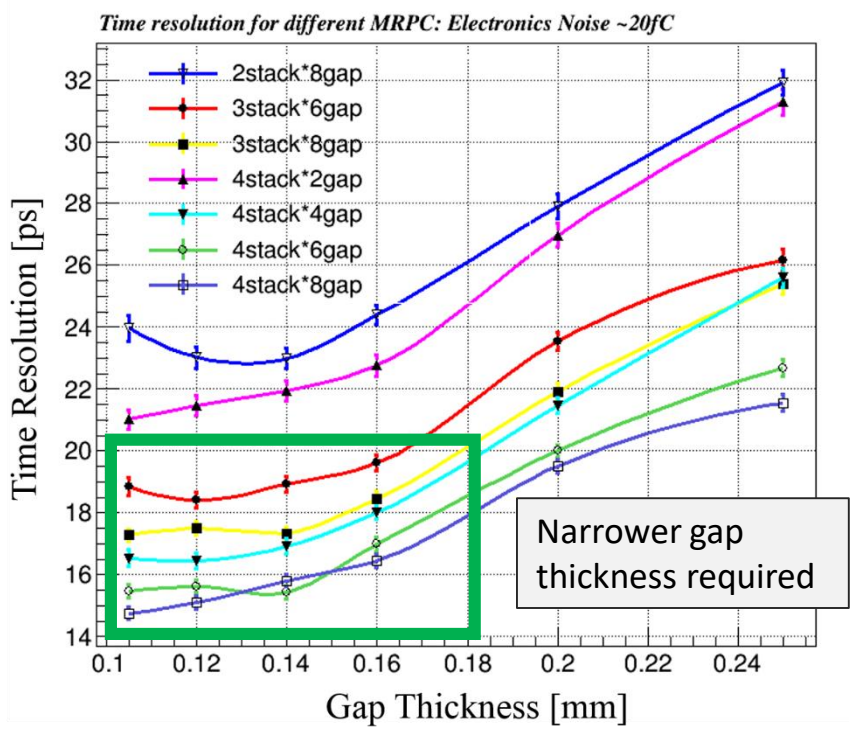
20ps MRPC for SoLID-TOF



$$\sigma_{TOF} = \sqrt{\sigma_{MRPC} + \sigma_{electronics}}$$

σ_{TOF} <20 ps, the intrinsic resolution of narrow gaps MRPC is around 15ps, so the time jitter of readout electronics <13~15 ps。

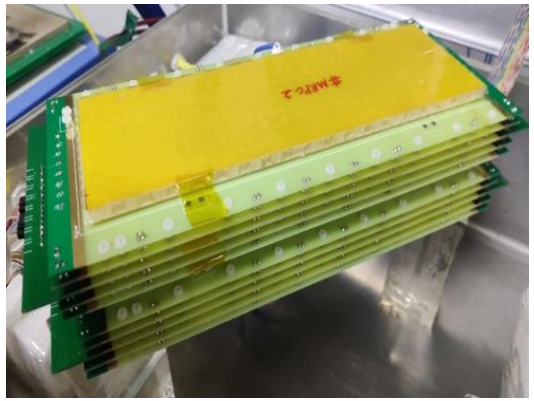
- Simulation indicates proper ways to design the gap thickness and arrange the stacks



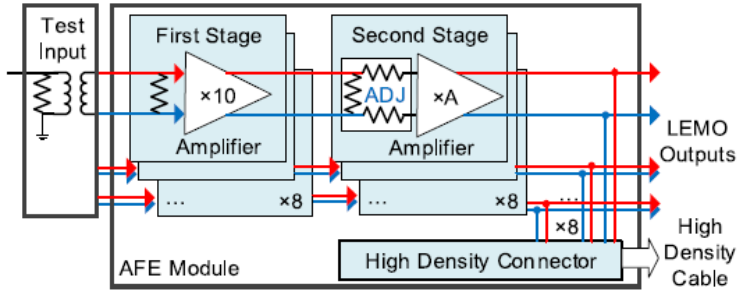
σ_{MRPC} <20 ps, the gas gap: <0.18mm

gap number: >16

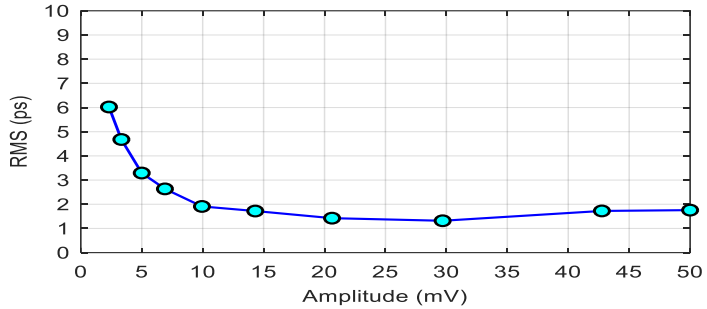
MRPC and electronics

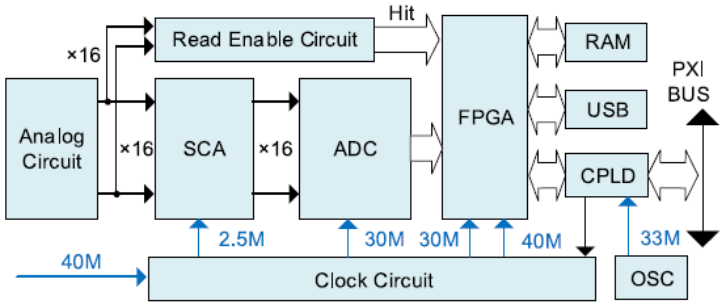


	MRPC prototype
gas gap thickness	128 μm
number of gas gaps	4 chambers × 8 gaps
glass material	**low resistivity glass**
glass thickness	400
readout strips	5 mm in width (2 mm clearance)

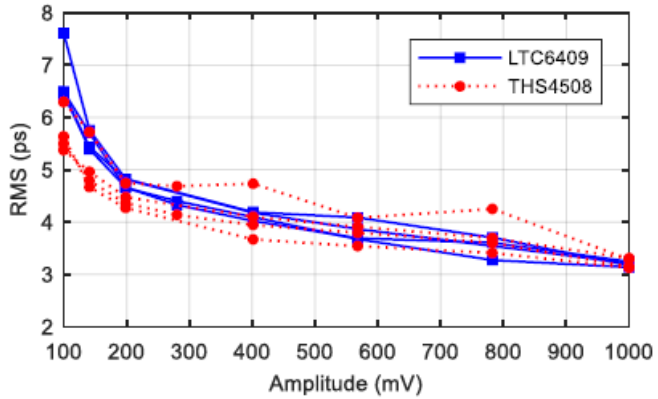


Fast amplifier
Bandwidth=1.4GHz



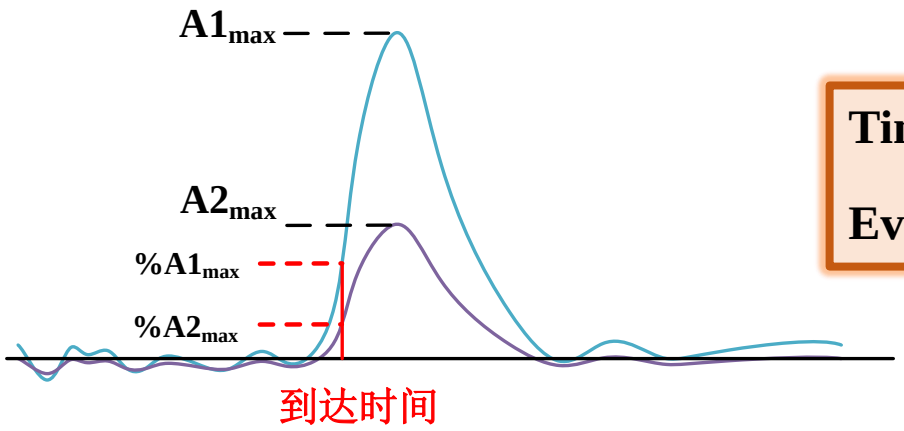


Waveform sampling
Based on DRS4
Sampling freq=5 GS/s



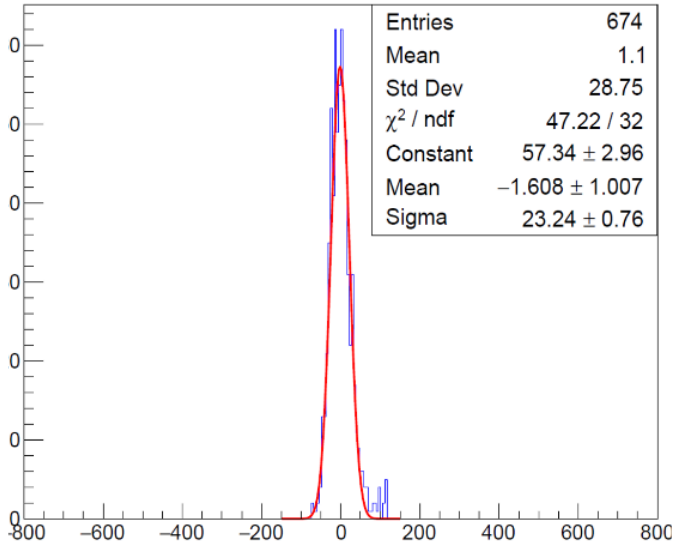
Test results

MRPC + fast amplifier + DRS4

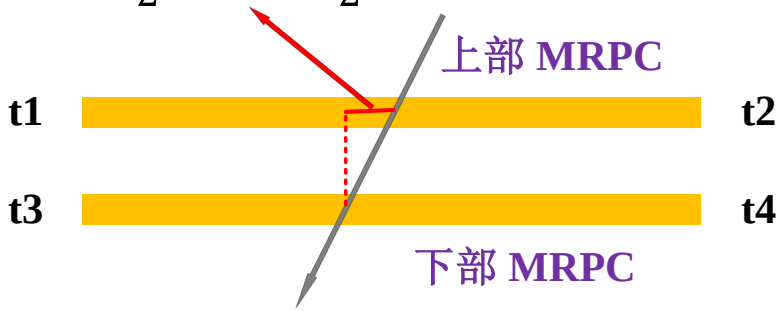


Timing：CFD

Event choose：Vertical cosmic ray

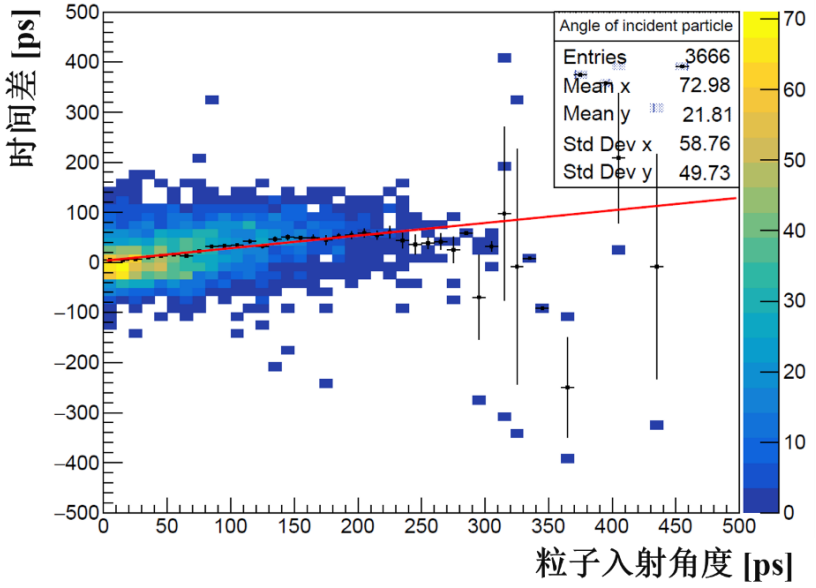


$$cut = [\frac{(t1-t2)}{2} - \frac{t3-t4}{2}] < 3\sigma_{\Delta t}$$



$$\Delta t = (t1+t2)/2 - (t3+t4)/2$$

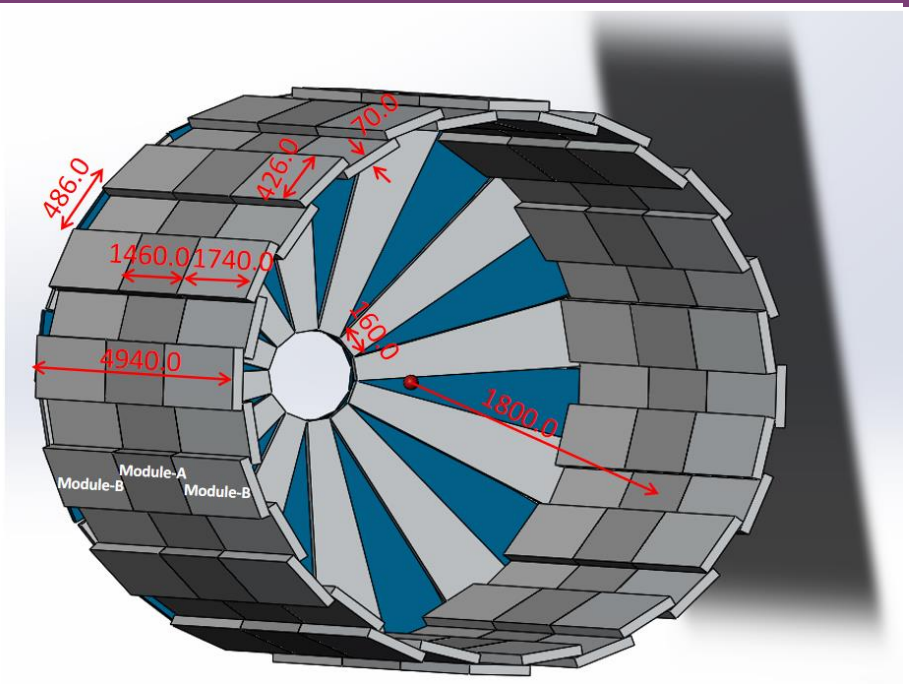
$$\sigma_{MRPC} = \sigma_{\Delta t}/\sqrt{2}$$



- Total time resolution

$$\sigma = \frac{23.24ps}{\sqrt{2}} = 16.43ps$$

CEPC-TOF总体构造



性能：

1、时间分辨：<35ps

2、PID of π/k：2.5GeV @3σ

3、TOF面积：~77m^2

4、电子学道数：37632

5、电子学功耗：17mW/道

6、造价估算：3420万RMB (MRPC 784万元)

7、材料厚度：0.1X$_0$

桶部：

绕筒圆周方向两层tower overlap，每层16个tower，每个tower包含1个module-A和2个module-B，覆盖角度为360°，沿筒轴向放置tower（tower长4.9m）。

Module-A、Module-B中两相邻的MRPC之间2条读出条重叠，读出条为10+2.5mm，4室6气隙单个探测器厚3.02cm。

端部：

一端共24个module，分两层overlap；每个module中有5个探测器，两相邻的MRPC之间1-2条读出条重叠，每个探测器有24个读出条，读出条为10+3.5mm

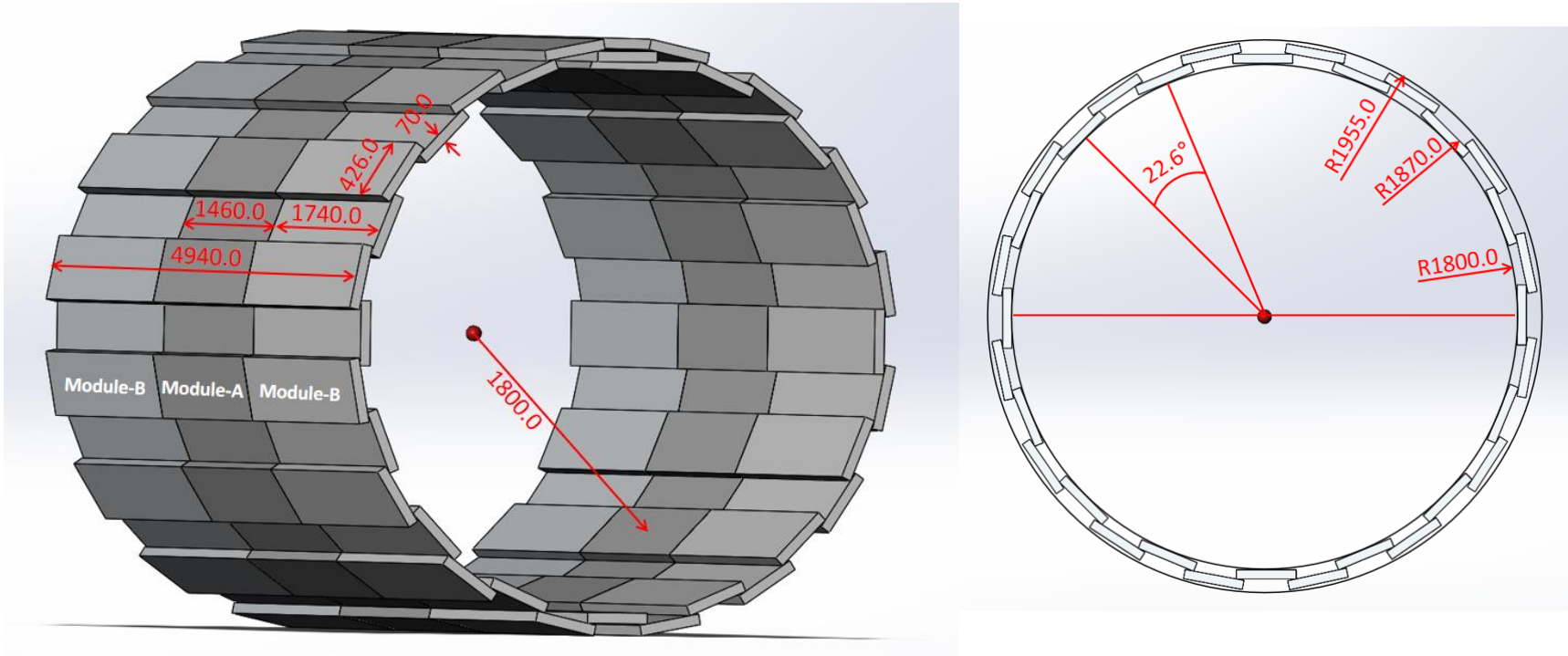


Figure 1.1 Main sizes of the TOF barrel.

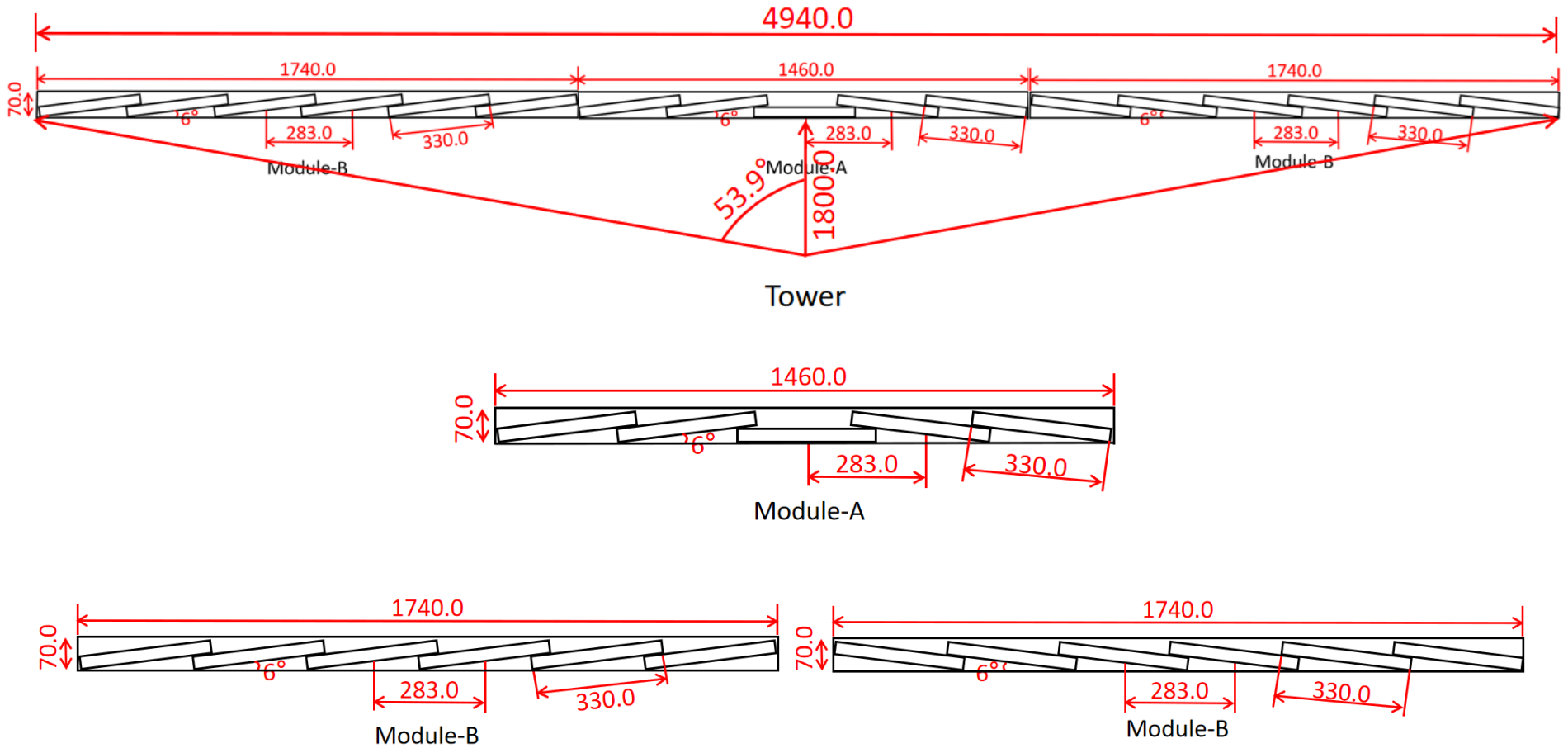


Figure 1.2 Arrangement of MRPCs inside the box along the beam direction.

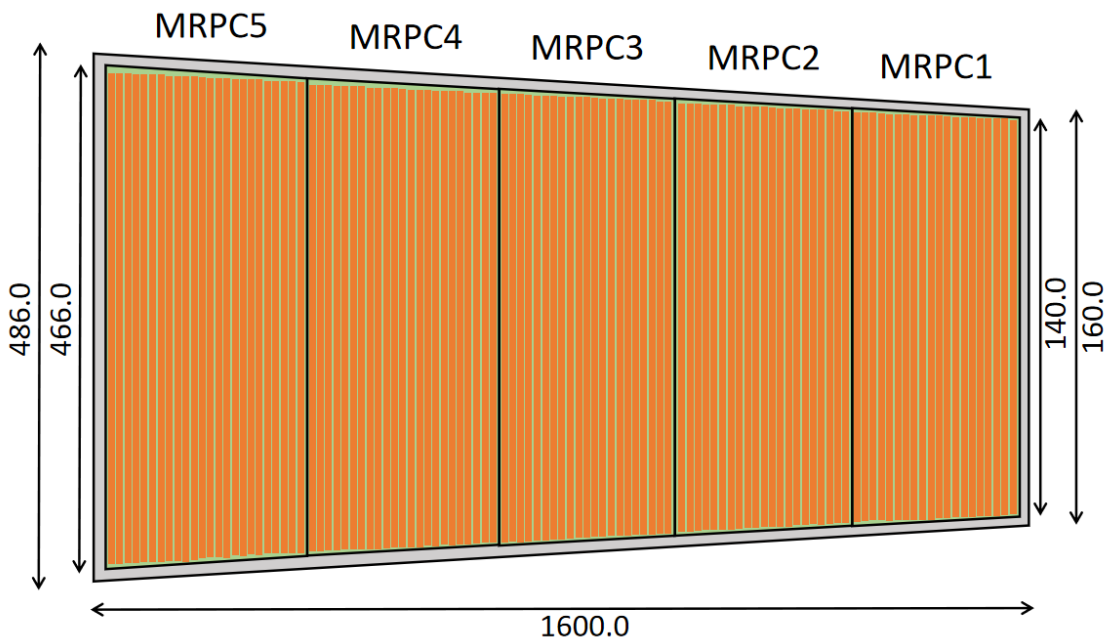


Figure 1.3 Arrangement of MRPCs inside the box in the End-cap.

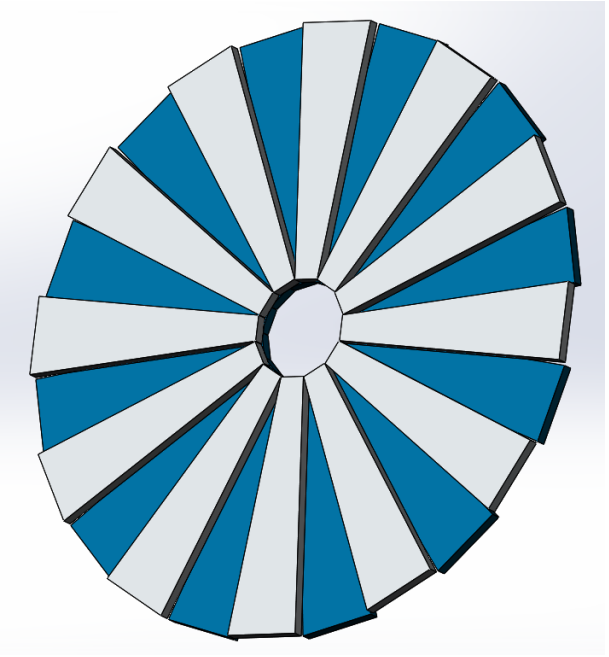


Figure 1.4 Diagram of the End-cap.

电子学通道设计：

Table 1.1 Main parameters of the TOF system.

		Number of detectors	Number of readout strips	Sensitive area, m^2	Number of FEE cards	Number of FEE channels
Barrel	$MRPC_B$	1	24	0.11	3	48
	Module-A	5	120	0.55	15	240
	Module-B	6	144	0.66	18	288
	Barrel Tower	17	408	1.87	51	816
	$Total_B$	544	13056	59.84	1632	26112
End-cap	$MRPC_E$	1	24	0.07	3	48
	Module-C	5	120	0.35	15	240
	$Total_E$	240	5760	16.80	720	11520
Total		784	18816	76.64	2352	37632

*A barrel tower contains one Module-A and two Module-B.

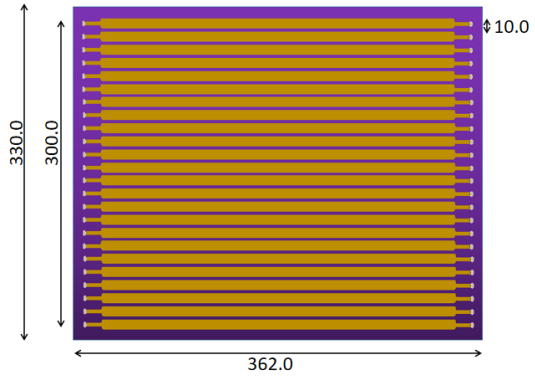
MRPC采用4室6气隙结构，气隙厚度0.14mm，单个探测器厚3.02cm

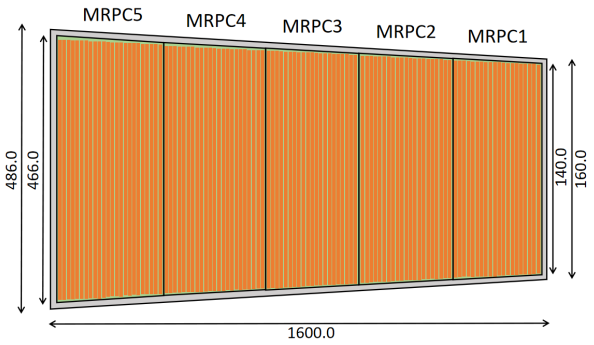
Table 1.2 Main parameters of one MRPC detector in the Barrel

Name of component	Dimensions (mm)	Quantity
Honeycomb	300×362×6	2
PCB	330×366×0.8	5
Mylar	300×362×0.25	8
Float glass	300×362×0.3	28
Gas gap	0.140	24
Readout strip	362×(10+2.5)	24

Table 1.3 Main parameters of one MRPC detector in the End-cap

Name of component	Dimensions (mm)	Quantity
Honeycomb	324×(462~136)×6	2
PCB	354×(466~140)×0.8	5
Mylar	324×(462~136)×0.25	8
Float glass	324×(462~136)×0.3	28
Gas gap	0.140	24
Readout strip	(466~140)×(10+3.5)	24





能量损失

Table 1.4 The TOF material budget

Material	**Energy Loss $\Delta E/E_0$ (%)**
2 plates of Honeycomb	0.09
5 PC boards	2.23
8 Mylars	0.72
28 MRPC glass plates	6.94
Total	9.98

For 1.5GeV electron, the material is ~0.1X_0

谢谢！