



# High time resolution MRPC of SPD-ToF

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# Outline

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- High time resolution MRPC can be used in SPD-ToF
- MRPC for SPD-ToF:

Have both higher counting rate( $1\text{kHz}/\text{cm}^2$ ) & high time-resolution prototype(50ps)

Use Eco-friendly working gas

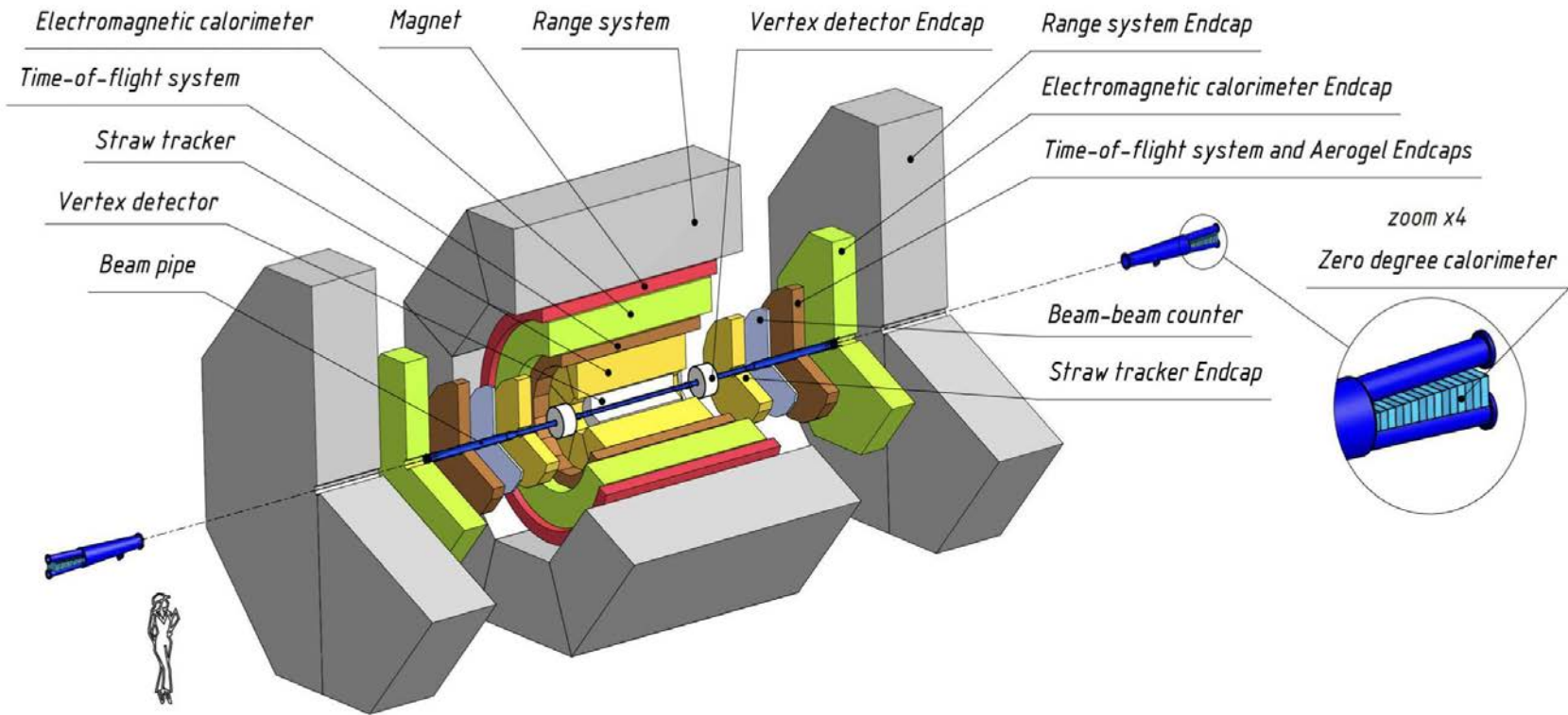
Use sealed MRPC to reduce gas flow

Use FEE readout system for less usage of storage space & network bandwidth

Structure of barrel ToF and end-cap ToF

- Summary

# Layout of SPD-ToF system



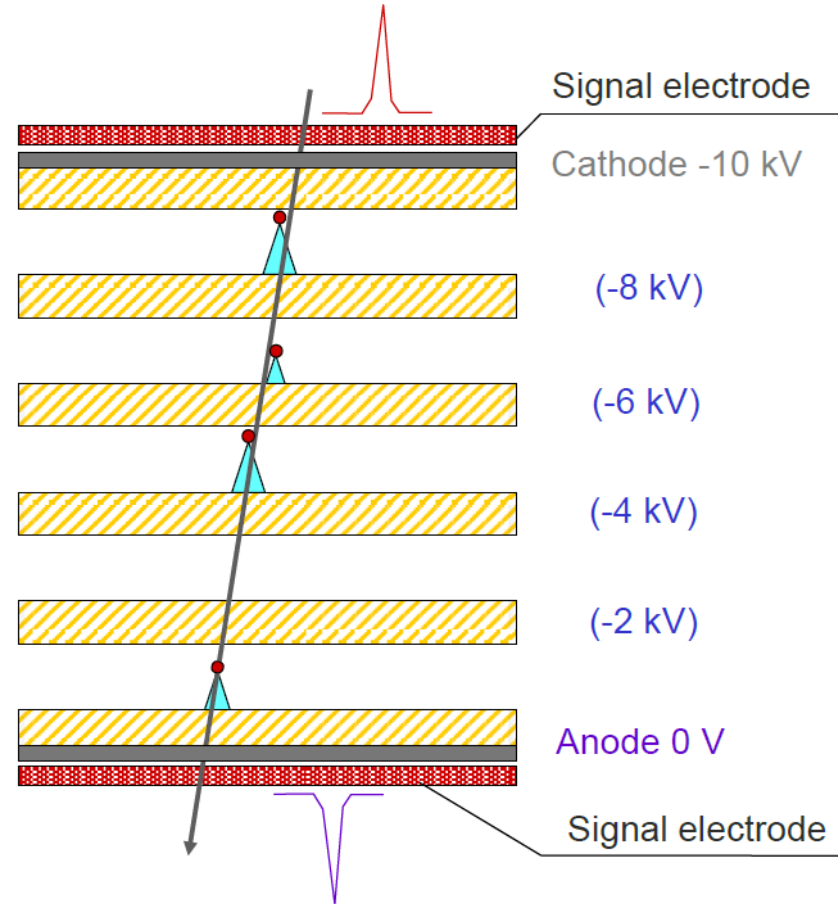
Requirement for TOF system	Parameters
Particle Identify	Few GeV at distance of 108cm
Time resolution	Better than 50ps
particle rate	0.1kHz/cm <sup>2</sup>
particle rate centre (end caps beam axis)	1kHz/cm <sup>2</sup>
Efficiency at kHz/cm <sup>2</sup>	>98%
Total area	27m <sup>2</sup>

# Multigap Resistive Plate Chamber (MRPC)

First proposed by E. C. Zeballos

## Traditional MRPC

- Electrode: high resistance material (e.g. glass)
- Gasgap thickness: 100 $\mu$ m-300 $\mu$ m
- Electric field strength:  $>10^5$  V/cm
- Gas mixtures: C<sub>2</sub>H<sub>2</sub>F<sub>4</sub> (90%) i- C<sub>4</sub>H<sub>10</sub> (5%) SF<sub>6</sub> (5%)
- Signal readout: readout strip



Narrow gap



High time precision

Enough gap thickness



good efficiency

# MRPC in ToF system

MRPC has been widely adopted to construct the Time of Flight (TOF) systems in HEP experiments.

	ALICE	STAR	FOPI	BESIII	In construction CBM	Proposed SoLID
Active area per detector (cm)	120 x 13	22 x 8.4	90 x 4.6	0.5x(9.2+14.8)x 32.8	33 x 27.6	--
Total active area (m <sup>2</sup> )	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	10 x 0.25
Gas mixtures (C <sub>2</sub> H <sub>2</sub> F <sub>4</sub> / C <sub>4</sub> H <sub>10</sub> /SF <sub>6</sub> )	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	106
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 <sup>2</sup> )	50	10	50	50	30k	20k

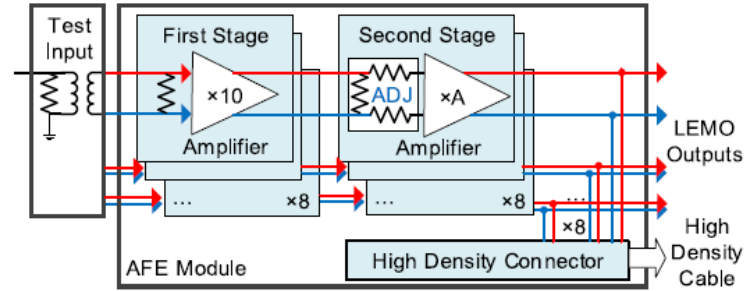
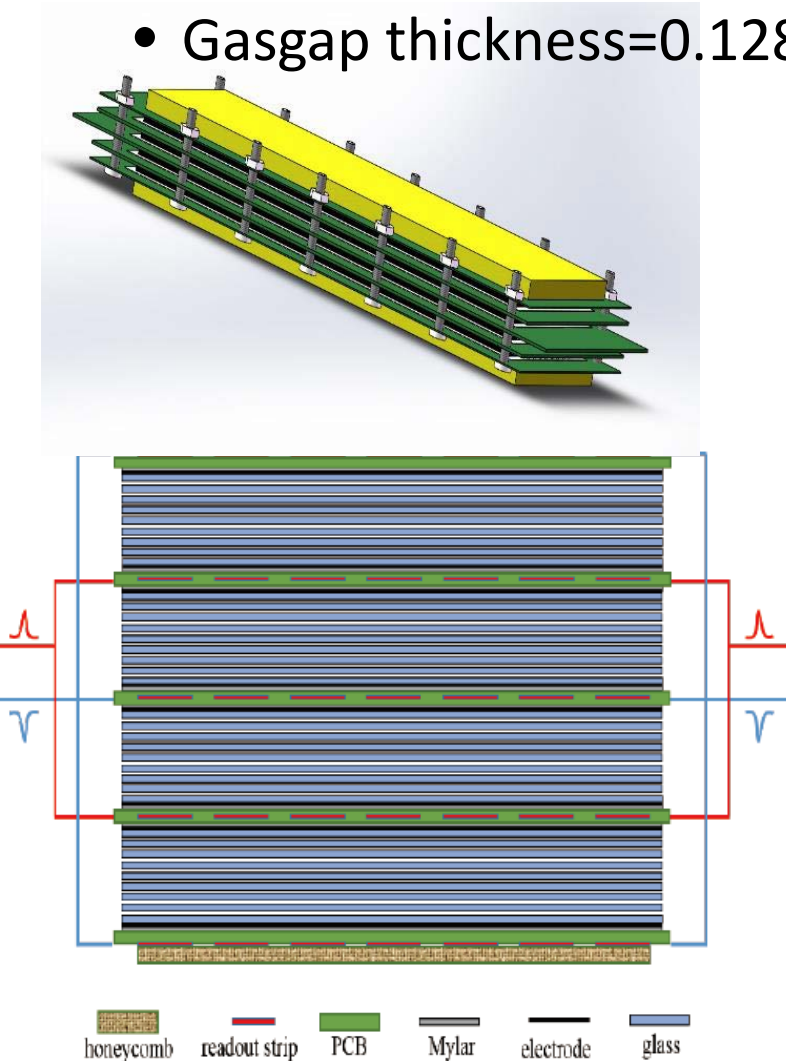
higher **counting rate** and **time precision**.

# High time resolution MRPC for SPD-ToF

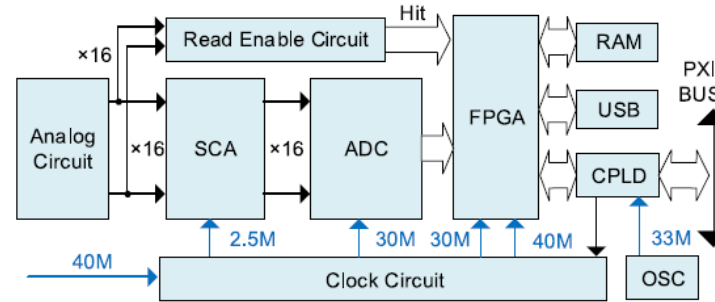
- High time resolution: 50ps
- Counting rate: better than 0.1kHz/cm<sup>2</sup>
- Lower gas pollution
  - Self-sealed MRPC test
  - Eco-friendly working gas
- Front-End-Electronic (FEE) and data acquisition system(DAQ)
- Structure of barrel ToF and end-cap ToF

# Higher counting rate & high time-resolution prototype

- 32gasgap MRPC
- Gasgap thickness=0.128mm



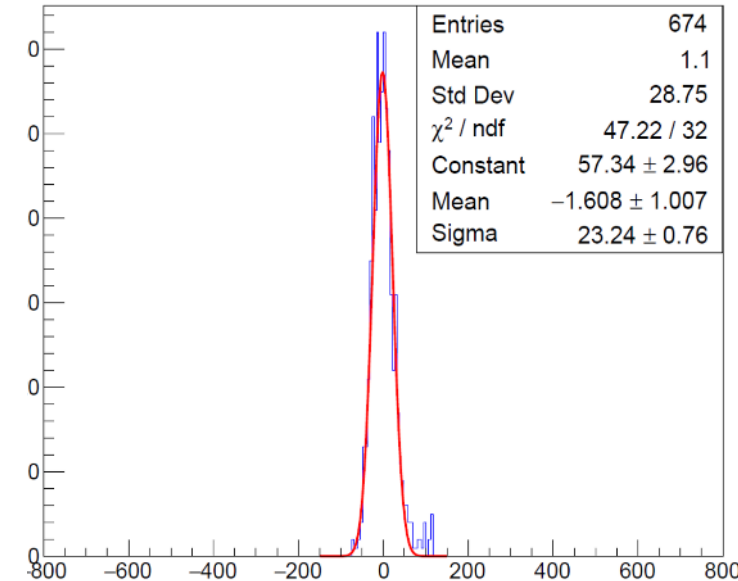
Fast amplifier  
Bandwidth=1.4GHz



Waveform sampling  
Based on DRS4

Sampling freq=5 GS/s

- Fast amplifier & Waveform sampling
- Electronic system time  $\sigma < 7\text{ps}$



- Total time resolution

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

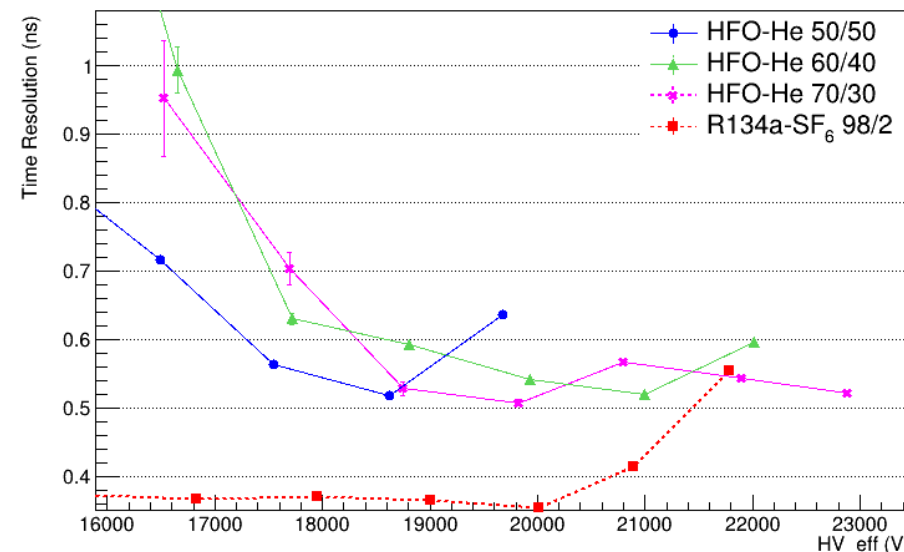
# Eco-friendly working gas

- The Global Warming Potential(GWP)

GWP is the heat absorbed by any greenhouse gas in the atmosphere, as a multiple of the heat that would be absorbed by the same mass of CO<sub>2</sub>.

Gas type	GWP(100 years)
CO <sub>2</sub>	1
HFC-134a	1430
SF <sub>6</sub>	23900
HFO-1234ze	4
He	<1

- Use HFO-He instead of HFC-SF<sub>6</sub>
- If HFO-1234ze/He 50/50, GWP=2.5



Time resolution of different gas mixture

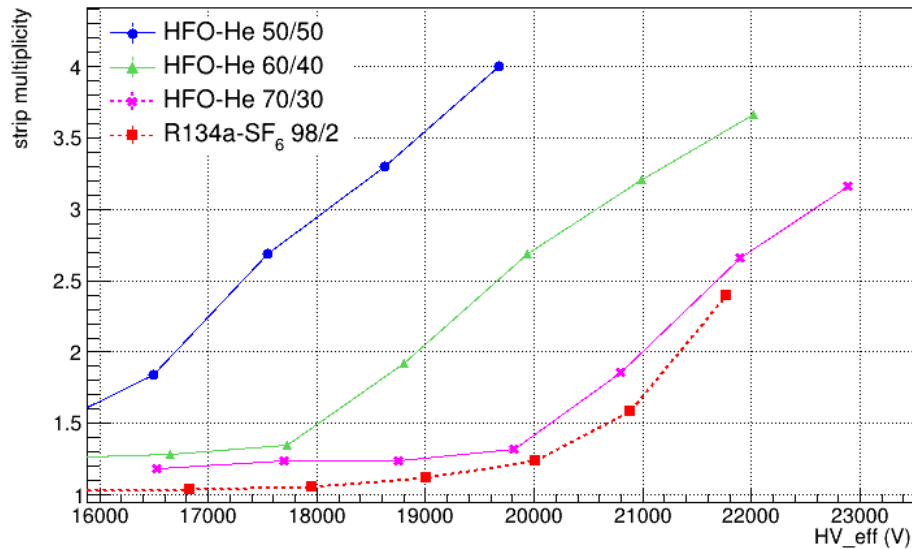
- Disadvantage
  - lower electron drift velocity->worse time resolution
  - lower electron drift velocity->bigger cluster size
  - less quenching->larger streamer fraction

The ecological transition of the EEE experiment, Marcello Abbrescia, Universita e INFN, Bari (IT)

<https://indico.cern.ch/event/1123140/contributions/5000797/>

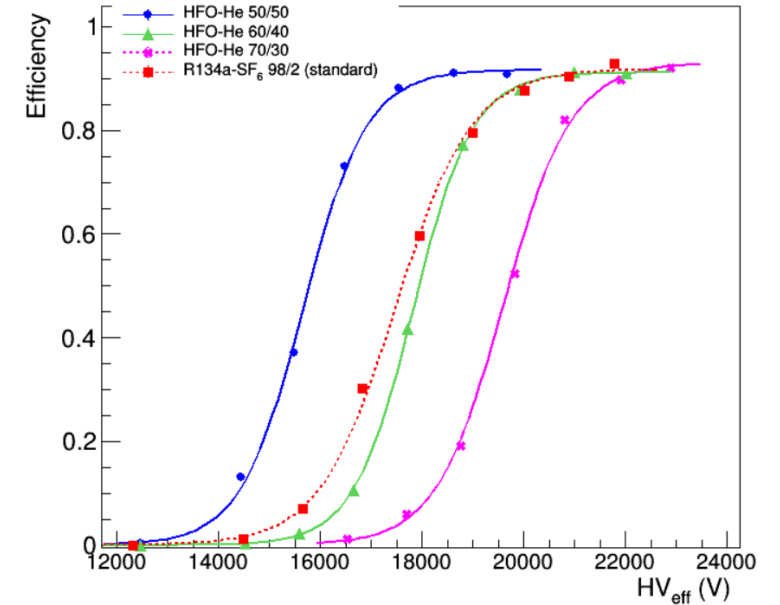


# Eco-friendly working gas



Cluster size of different gas mixture

- Disadvantage
  - lower electron drift velocity->worse time resolution
  - lower electron drift velocity->bigger cluster size
  - less quenching->larger streamer fraction



Efficiency of different gas mixture

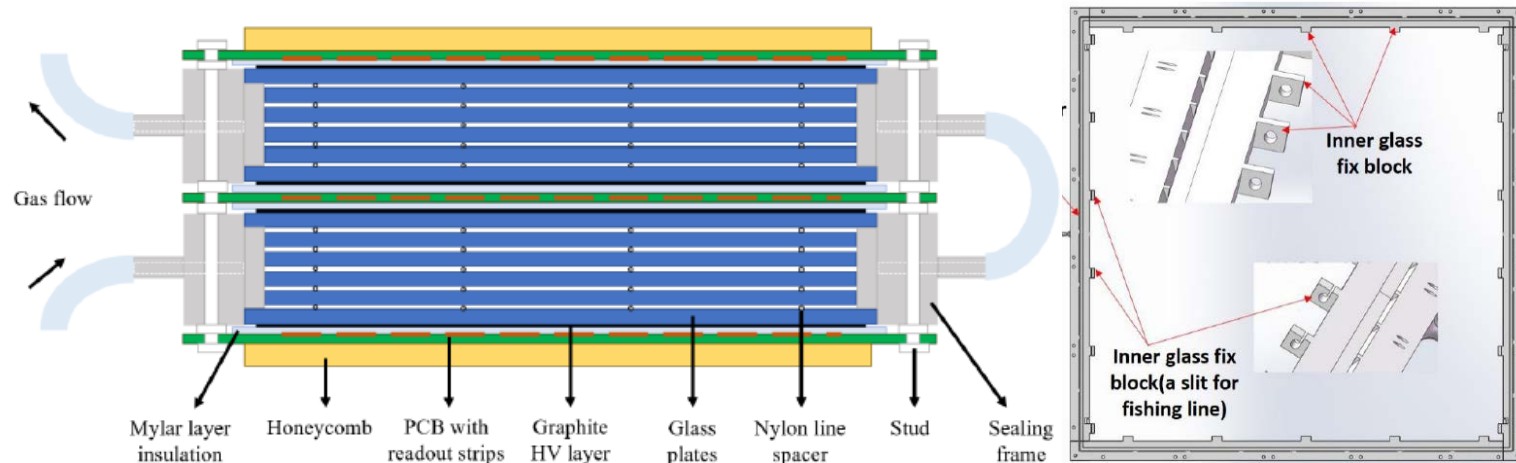
- Advantage
  - similar maximum efficiency
  - just 50% worse time resolution

The ecological transition of the EEE experiment, Marcello Abbrescia, Universita e INFN, Bari (IT)

<https://indico.cern.ch/event/1123140/contributions/5000797/>

# Sealed MRPC prototype cosmic test

- Sealed MRPC aims to reduce gas flow



- Sealed MRPC prototype:

10 gas gaps of  $250\mu\text{m}$  thickness

15mm strip width+2mm gap between strips

gas flow: less than **5sccm** for **1m<sup>2</sup>** sensitive area

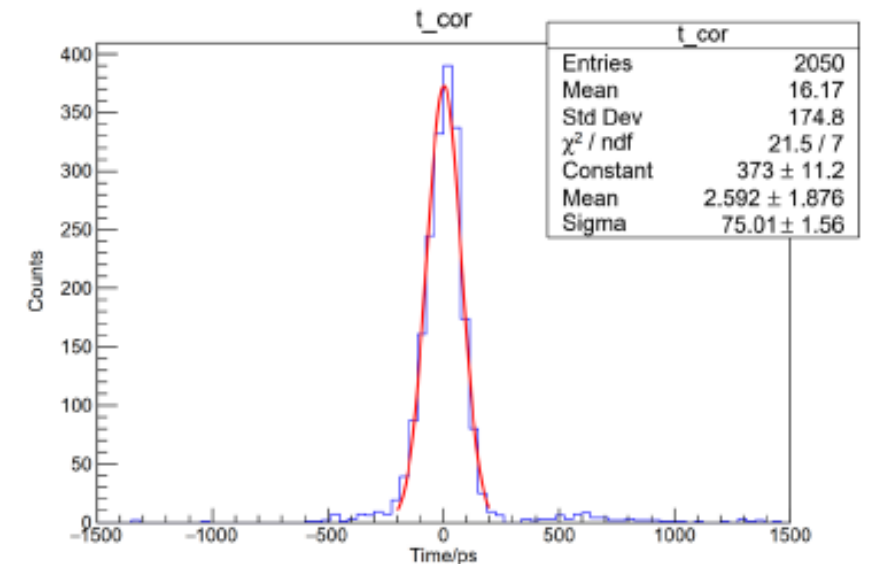
decreased by a factor of 10 compared with traditional MRPCs

- Cosmic test result

Efficiency=97%

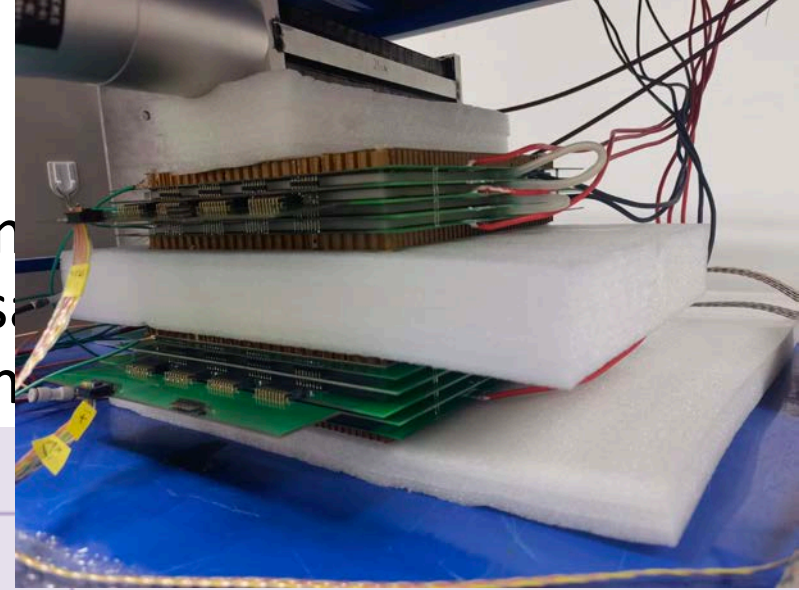
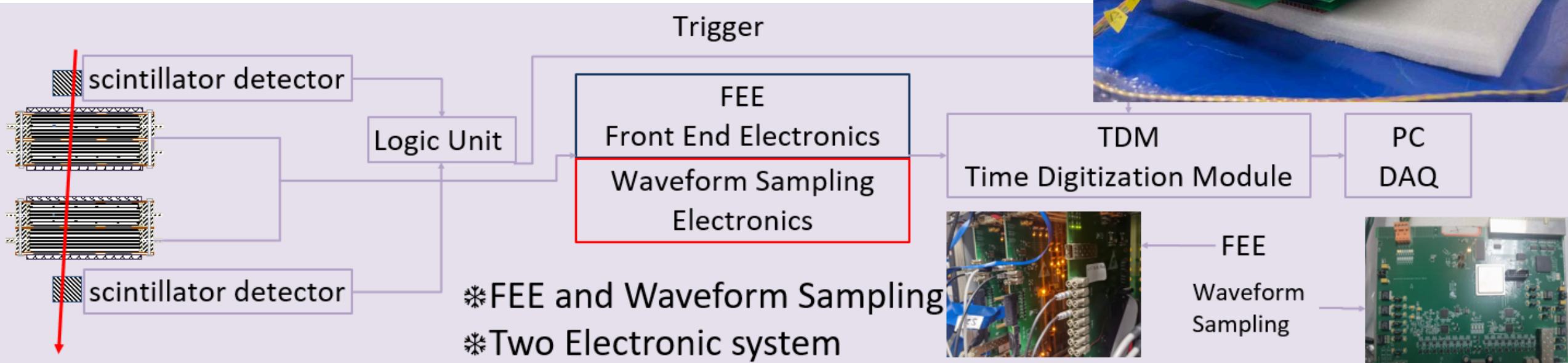
ToF  $\sigma=75.01\text{ps}$

Time resolution=53.05ps



# FEE readout cosmic test for SPD-ToF

- The Front-End Electronic (FEE) readout system uses much less space and network bandwidth compared with waveform sampling. The amount of data is about 1000 times smaller than waveform sampling.



- Both FEE and waveform sampling are used for the readout of the signal, testing a new **sealed** MRPC with 28 gasgap. The gasgap width is  $128\mu\text{m}$ .
- Aiming to demonstrate **the feasibility of FEE**.

# Structure of barrel ToF

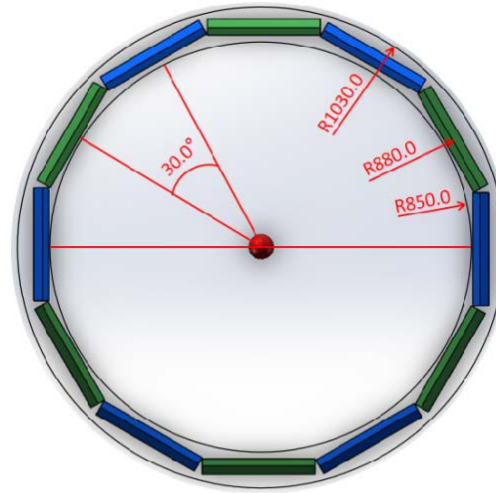
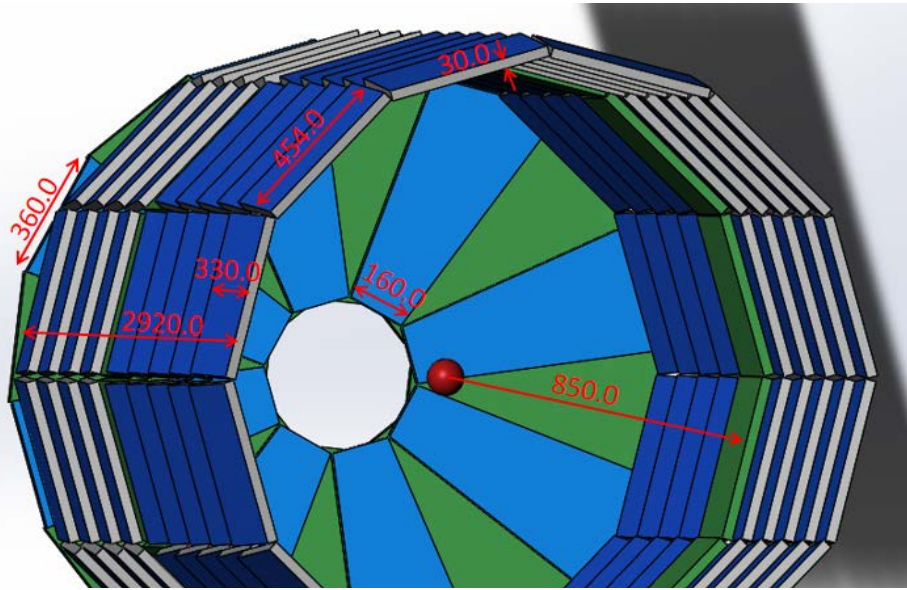


Figure 1.1 Main sizes of the TOF barrel in  $\phi$  direction.

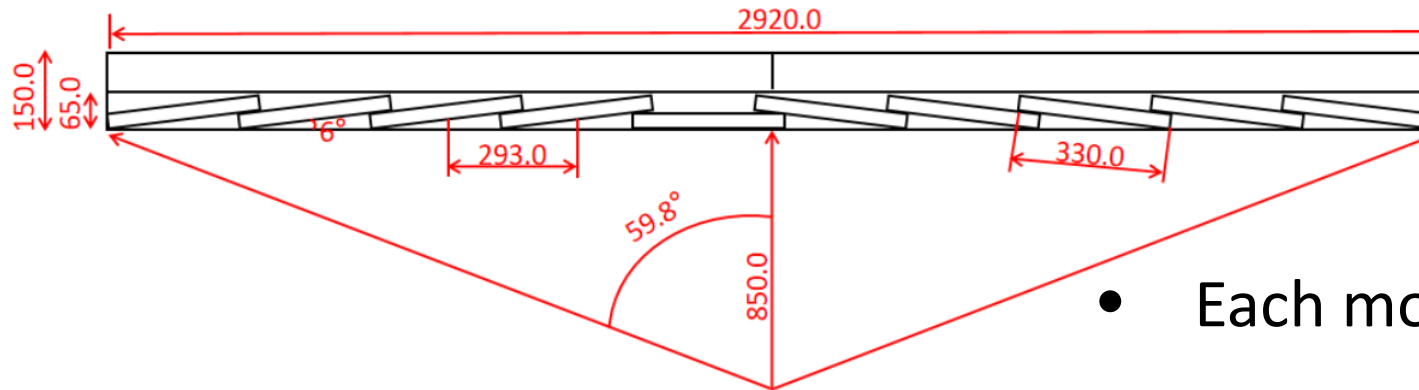


Figure 1.2 Arrangement of MRPCs inside the box along the beam direction.

- 12 module for one circle

Table 1.2 Main parameters of one MRPC detector in the Barrel

Name of component	Dimensions (mm)	Quantity
Honeycomb	$300 \times 450 \times 6$	2
PCB	$330 \times 454 \times 0.8$	5
Mylar	$300 \times 450 \times 0.25$	8
Float glass	$300 \times 450 \times 0.3$	28
Gas gap	0.128	24
Readout strip	$454 \times (10+2.5)$	24

- Each module consists of 10 sealed MRPC

# Structure of end-cap TOF

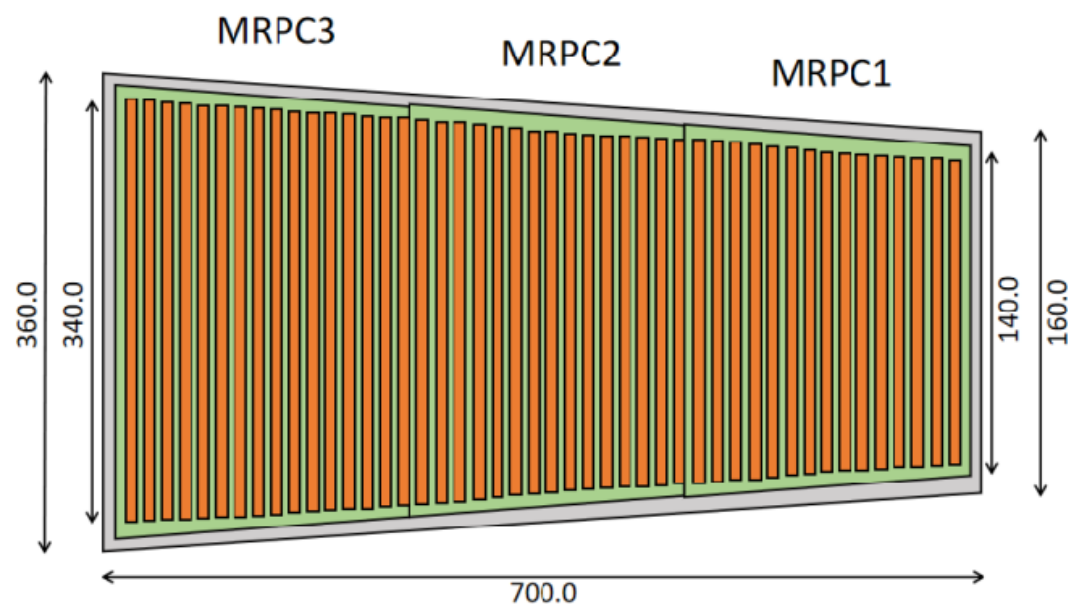


Figure 1.3 Arrangement of MRPCs inside the box in the End-cap.

- eTOF consists of 16 modules and each module consists of 3 sealed MRPC.

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

Name of component	Dimensions (mm)	Quantity
Honeycomb	$216 \times (336 \sim 136) \times 6$	2
PCB	$246 \times (340 \sim 140) \times 0.8$	5
Mylar	$216 \times (336 \sim 136) \times 0.25$	8
Float glass	$216 \times (336 \sim 136) \times 0.3$	28
Gas gap	0.128	24
Readout strip	$(340 \sim 140) \times (10 + 3.5)$	16

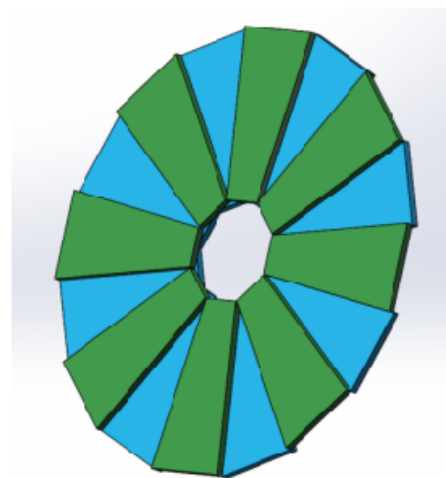


Table 1.1 Main parameters of the TOF system.

		Number of detectors	Number of readout strips	Sensitive area, m <sup>2</sup>	Number of FEE cards	Number of FEE channels
Barrel	MRPC <sub>B</sub>	1	24	0.14	3	48
	Module <sub>B</sub>	10	240	1.4	30	480
	Total <sub>B</sub>	120	2880	16.8	360	5760
End-cap	MRPC <sub>E</sub>	1	16	0.06	2	32
	Module <sub>E</sub>	3	48	0.18	6	96
	Total <sub>E</sub>	96	1536	5.8	192	3072
Total		216	4416	22.6	552	8832



# Summary

High time resolution MRPC can be used in SPD-ToF

For SPD-ToF, MRPC system should:

- Have both higher counting rate& high time-resolution prototype(50ps).
  - Prototype has been examined its 96% efficiency and 20 ps resolution at 20 kHz/cm<sup>2</sup> rate condition.
- Use Eco-friendly working gas.
  - Need further experiment.
- Use sealed MRPC to reduce gas flow.
  - Sealed MRPC with a gas flow <5sccm/m<sup>2</sup> sensitive area reach a 53ps time resolution in cosmic test.
- Use FEE readout system for less usage of storage space & network bandwidth.
  - Testing.
- Structure of barrel ToF and end-cap ToF.