MRPC mass production and test for the BESIII E-TOF upgrade

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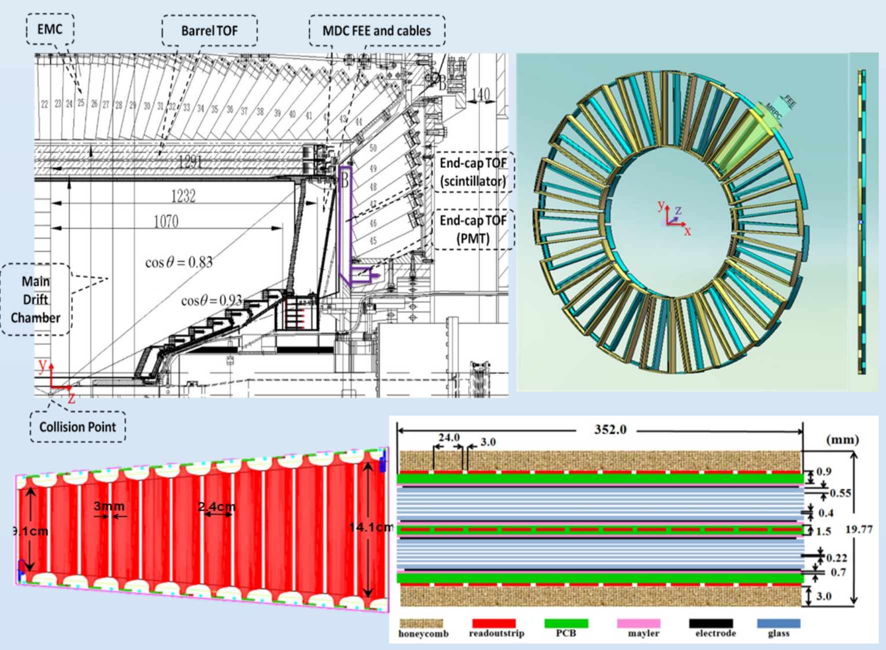
The end-cap Time-of-Flight (E-TOF) system of Beijing Spectrometer (BESIII) is being upgraded based on the Multi-gap Resistive Plate Chamber (MRPC) technology. The mass production and test of the MRPC modules are carried on by the TOF group of USTC. The test results show that all the produced MRPCs have stable performance and meet the quality standard in mass production. After subtracting the contribution from the electronics and muon momentum effect, an intrinsic time resolution of better than 60 ps can be achieved for the cosmic rays (MIPs) .

Design and Production

The BESIII is a high precision general-purpose detector designed for high luminosity e^+e^- collisions in the τ-charm energy region at the Beijing Electron Positron Collider (BEPCII). The two BESIII end-cap rings will be fully covered by 2×36 trapezium MRPC modules.



The goal of the BESIII E-TOF upgrade

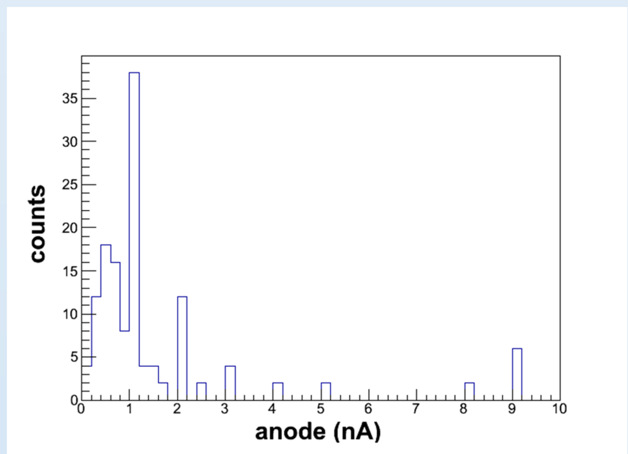
- An overall time resolution of 80 ps for MIPs
- The K/π separation (2σ) momentum range. can be extended from 1.1 GeV/c to 1.4 GeV/c.
- The intrinsic MRPC time resolution (including the electronics) is required to be better than 55 ps.

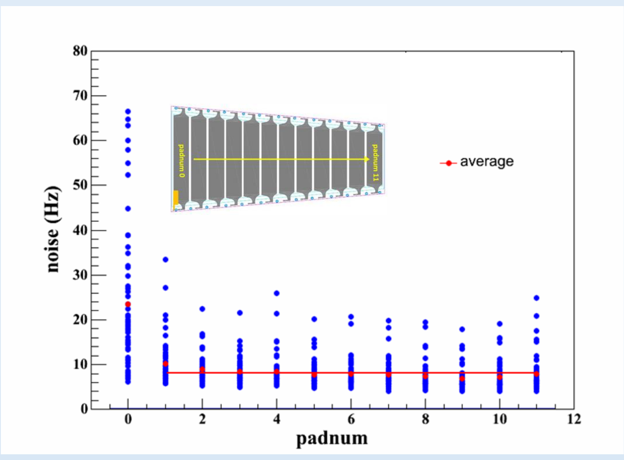
The MRPC modules

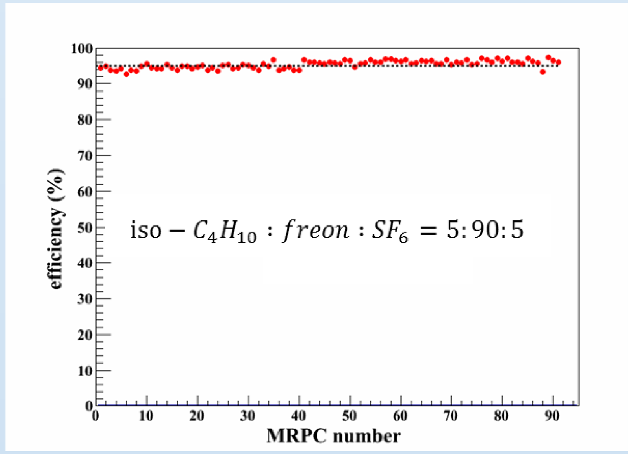
- 2×6 uniform gas gaps with 0.22mm thick.
- 12 double-end readout strips with the length arranging from 9.1 cm to 14.1 cm and 2.4 cm wide.
- The gap between any adjacent strips is 4 mm.
- The total thickness is less than 20 mm.

In total, 72 MRPC modules have been produced and completely installed in BESIII in 2015.

Performance

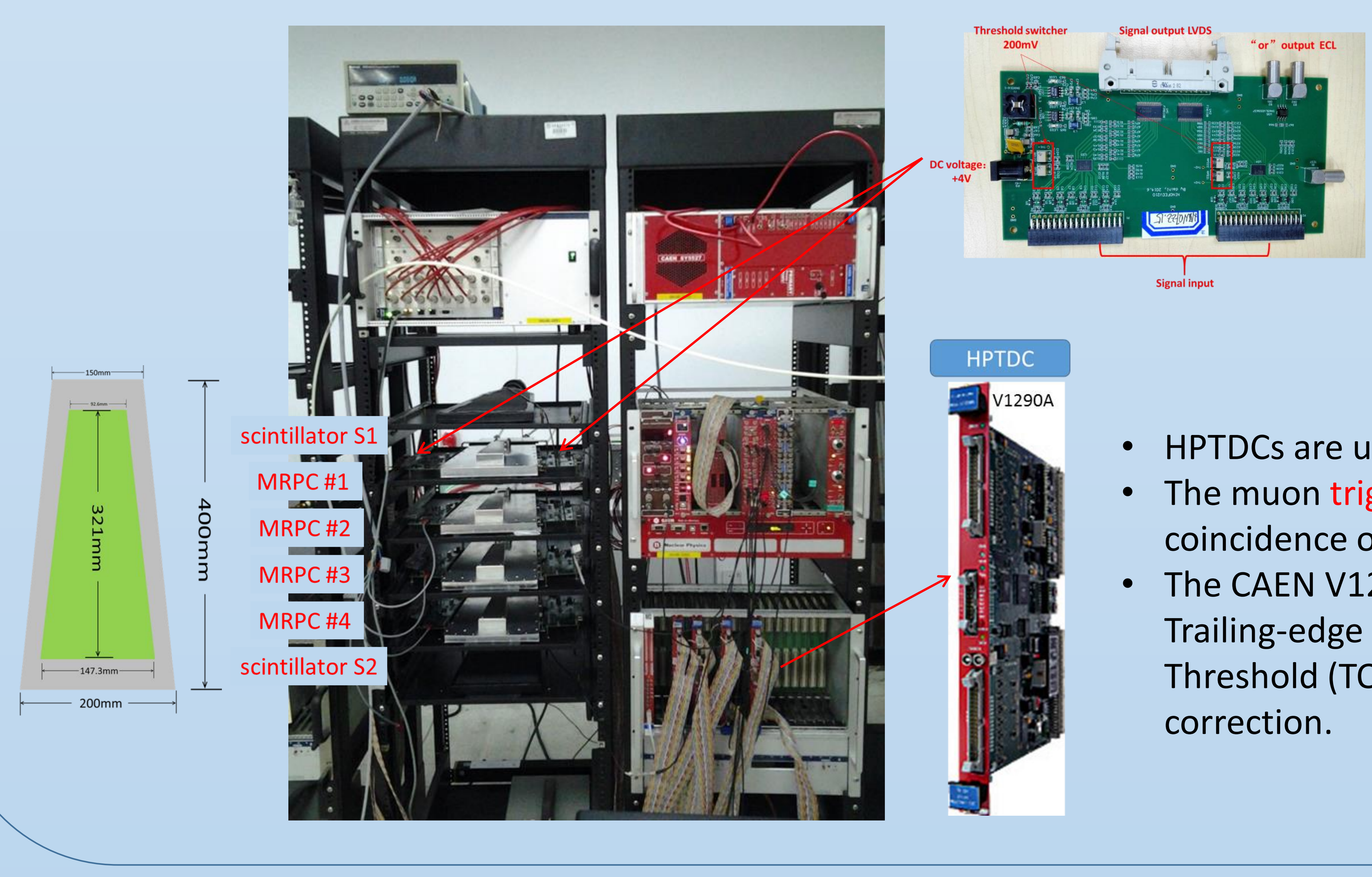






- The operating HV of MRPC modules is selected to be ±7300V.
- The dark current and the noise rate are tested before further measurements.
- The detection efficiency is ~95% at the operating HV.

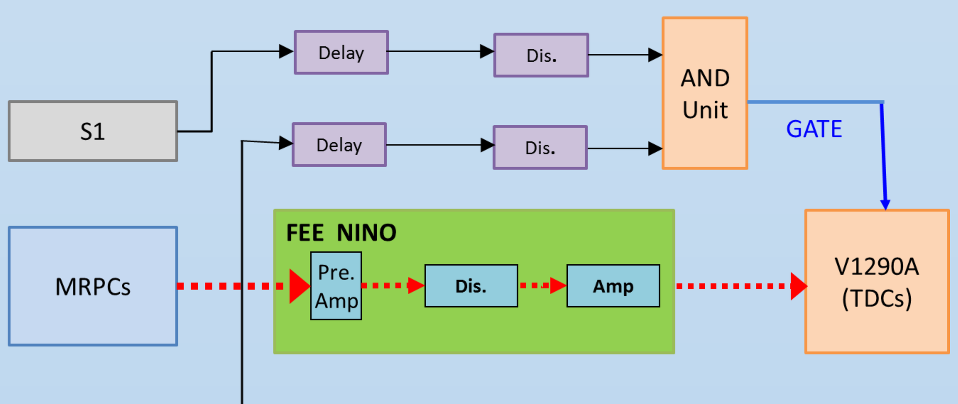
Cosmic ray platform and test method



The front-end electronics (FEE) are 16-channel amplifier/discriminator cards based on the NINO chip designed by the Institution of High Energy Physics (IHEP) Chinese Academy of Sciences.

- Measuring TOT (Time-Over-Threshold) instead of charge.
- Producing a signal that is the OR of all 16 channels.
- The total time resolution of the readout electronics is no more than 30ps.

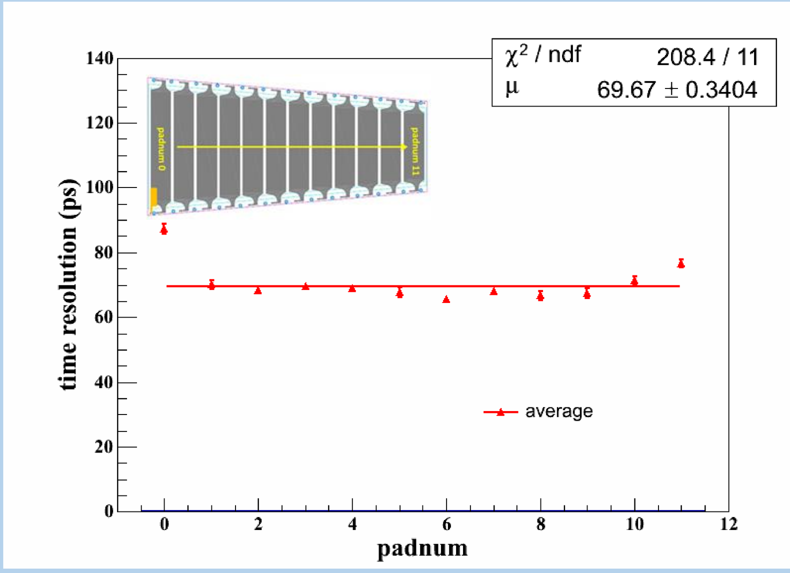
- HPTDCs are used in trigger mode;
- The muon trigger for four HPTDCs is generated by the coincidence of the two scintillators;
- The CAEN V1290A HPTDC can record the Leading- and Trailing-edge of the discriminated signals. The Time-Over-Threshold (TOT) of the signal is thus used for the slewing correction.



The logic diagram of the cosmic ray test DAQ system

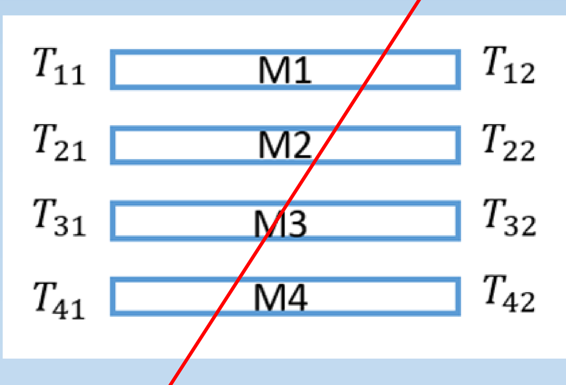
Time Resolution

Slewing correction and test result

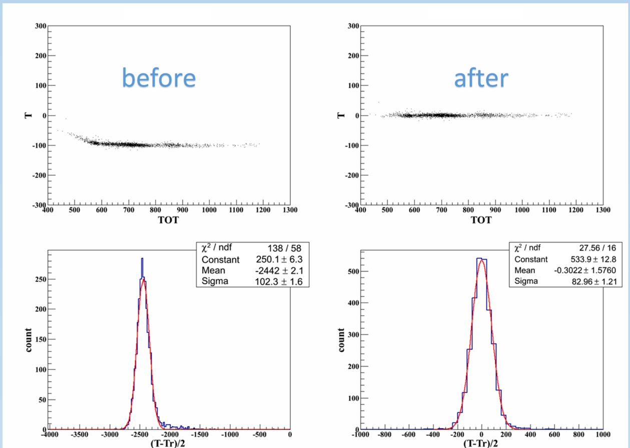


- The average time is used to determine the time resolution of the double-end readout MRPCs.
- The time resolution of all the strips of the entire MRPC module is measured.
- After the T-TOT correction, the average time resolution of each strip (including the electronics) is shown in the left figure.

The T-TOT correlation for each MRPC strip is fitted by the function below. The mean time of the other two MRPC modules is used as the reference time (Tr).



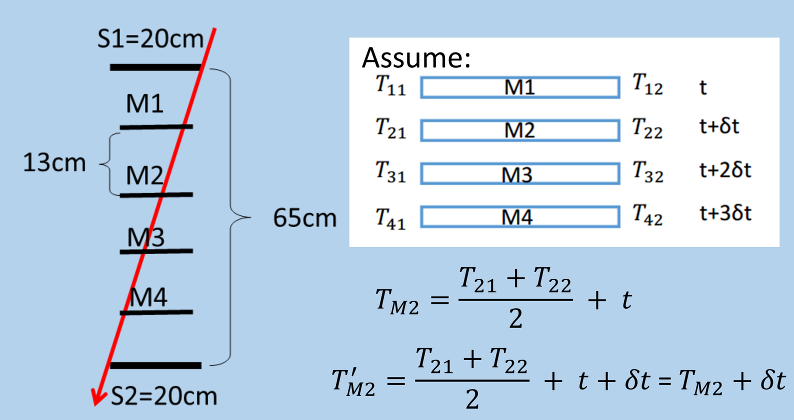
M1（Tr M2 M3）
M2（Tr M3 M4）
M3（Tr M1 M2）
M4（Tr M2 M3）



Slewing correction function: $f(x)=p_0+\frac{p_1}{\sqrt{x}}+\frac{p_2}{x}+\frac{p_3}{x\sqrt{x}}+\frac{p_4}{x^2}$

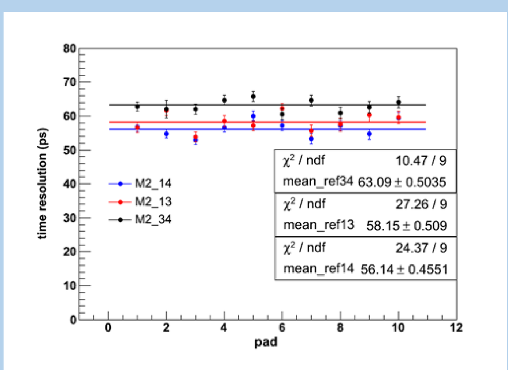
Muon Momentum Effects

Choosing different module combinations as reference (Tr) gives different time resolution, which mainly caused by the momentum distribution of the cosmic ray muons. Consider one module:



$$T_{M2}=\frac{T_{21}+T_{22}}{2}+t$$

$$T'_{M2}=\frac{T_{21}+T_{22}}{2}+t+\delta t=T_{M2}+\delta t$$



M2 (Tr:M3 M4) : $\sigma^2_{\left(T'_{M2}-\frac{T'_{M3}+T'_{M4}}{2}\right)}-\sigma^2_{\left(\frac{T'_{M3}-T'_{M4}}{2}\right)}=\sigma^2_{\left(T_{M2}-\frac{T_{M3}+T_{M4}}{2}\right)}-\sigma^2_{\left(\frac{T_{M3}-T_{M4}}{2}\right)}+2\sigma^2_{(\delta t)}$

M2 (Tr:M1 M3) : $\sigma^2_{\left(T'_{M2}-\frac{T'_{M1}+T'_{M3}}{2}\right)}-\sigma^2_{\left(\frac{T'_{M1}-T'_{M3}}{2}\right)}=\sigma^2_{\left(T_{M2}-\frac{T_{M1}+T_{M3}}{2}\right)}-\sigma^2_{\left(\frac{T_{M1}-T_{M3}}{2}\right)}-\sigma^2_{(\delta t)}$

M2 (Tr:M1 M4) : $\sigma^2_{\left(T'_{M2}-\frac{T'_{M1}+T'_{M4}}{2}\right)}-\sigma^2_{\left(\frac{T'_{M1}-T'_{M4}}{2}\right)}=\sigma^2_{\left(T_{M2}-\frac{T_{M1}+T_{M4}}{2}\right)}-\sigma^2_{\left(\frac{T_{M1}-T_{M4}}{2}\right)}-2\sigma^2_{(\delta t)}$

Estimate：

$\sigma^2_{\exp}=\sigma_i^2+2\sigma_p^2+\sigma_e^2$

σ_i:intrinsic time resolution;σ_p:muon momentum effects;

σ_e:intrinsic electronics time resolution together with TDC

$\sigma_i=\sqrt{69.67^2-2\times 15^2-30^2}=59\text{ps}$