OFFLINE DATA PROCESSING OF MRPC END CAP TOF@BESIII

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BINP-IHEP Seminar

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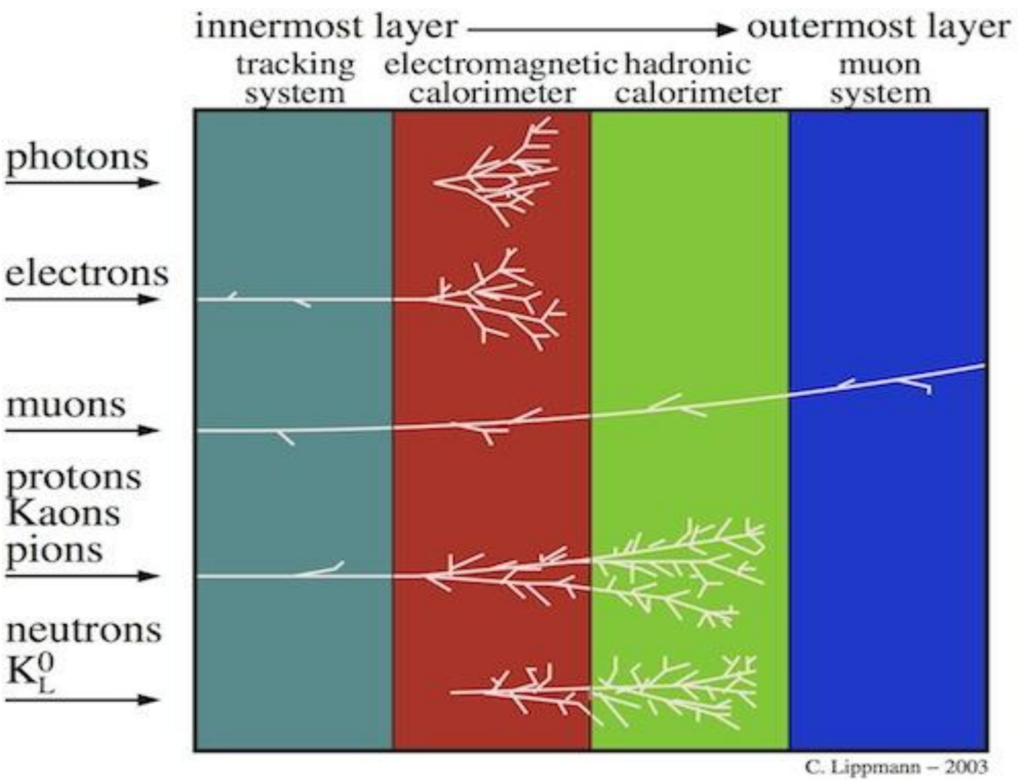
Outline

- Particle Identification (PID)
- Time-of-Flight Detector (TOF)
- Multi-gap Resistive Plate Chamber (MRPC)
- BESIII Endcap TOF system
    - Reconstruction
    - Calibration
- Summary

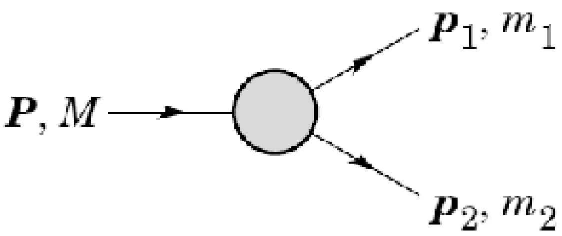
Detector Design

- A “traditional ” Detector
  - Vetex system
  - Tracking system
  - Particle identification
  - EM calorimeter
  - Hadron calorimeter
  - Muon system
- Particle identification is a crucial aspect.

$$r, e, \mu, \pi, K, p$$
$$(\vec{p}, E)$$



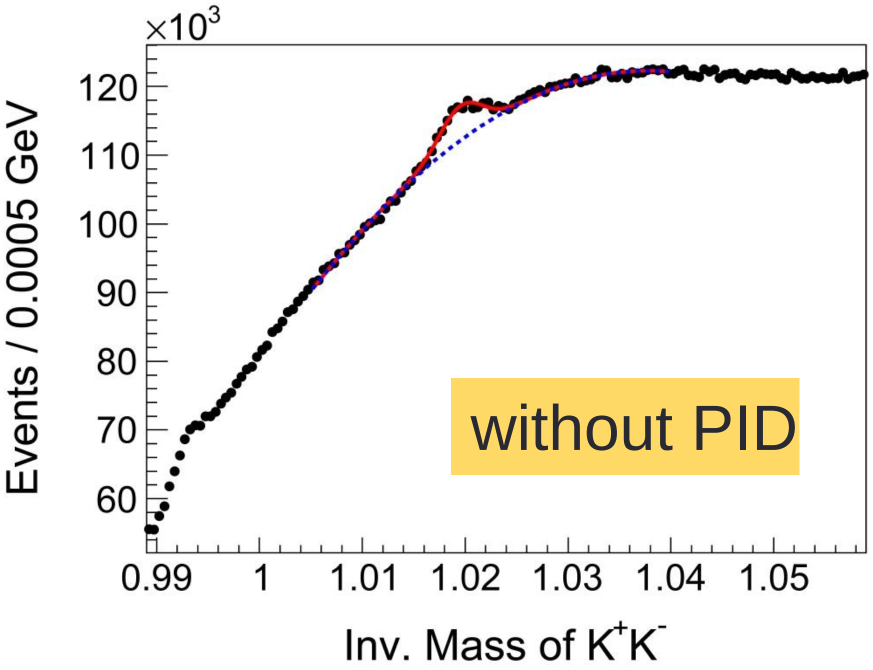
WHY PID is crucial?

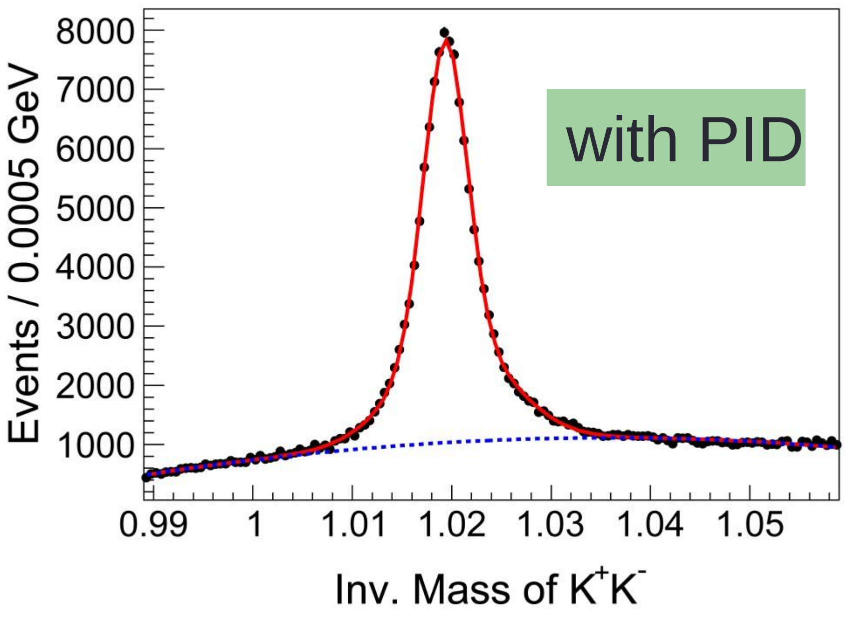


- Invariant mass

$$M^2 = m_1^2 + m_2^2 + 2(E_1 E_2 - p_1 p_2 cos\theta)$$

- Improvement in the signal-to-background ratio





$$\phi \rightarrow K^+ K^-$$

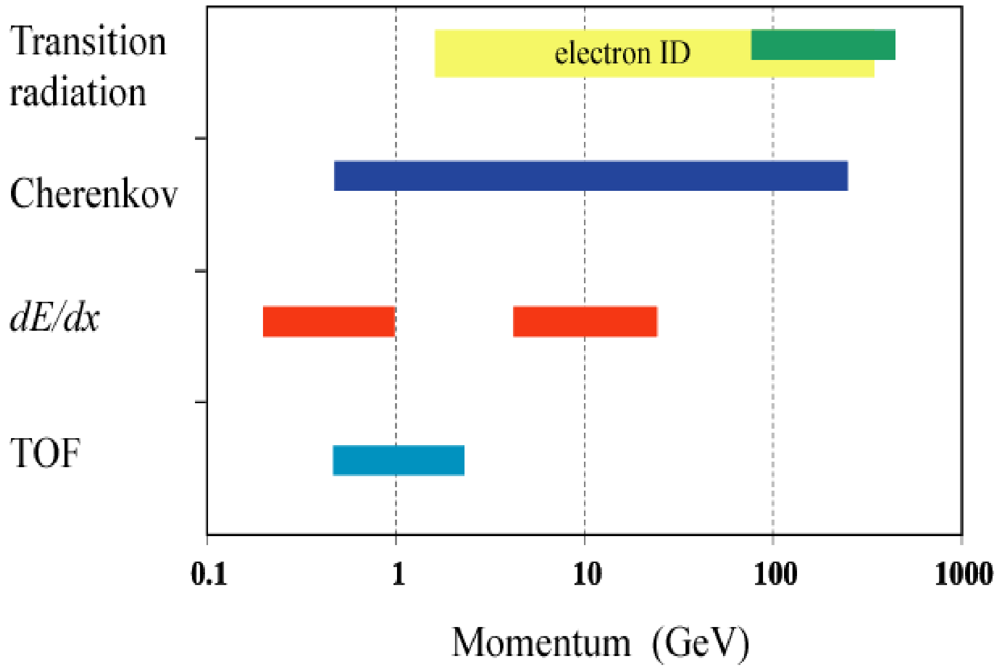
Particle Identification (PID)

- Measurement of the energy deposit by ionization $\beta\gamma$
- Time-of-flight measurements β
- Detection of Cherenkov radiation β
- Detection of transition radiation γ

$$\beta \equiv \frac{v}{c} = \frac{|\vec{p}|c}{E}$$

$$\gamma \equiv \frac{1}{\sqrt{1-\beta^2}} = \frac{E}{mc^2}$$

$$p = \gamma m v \rightarrow m = \frac{p}{c\beta\gamma}$$



Time-of-Flight (TOF) Detector

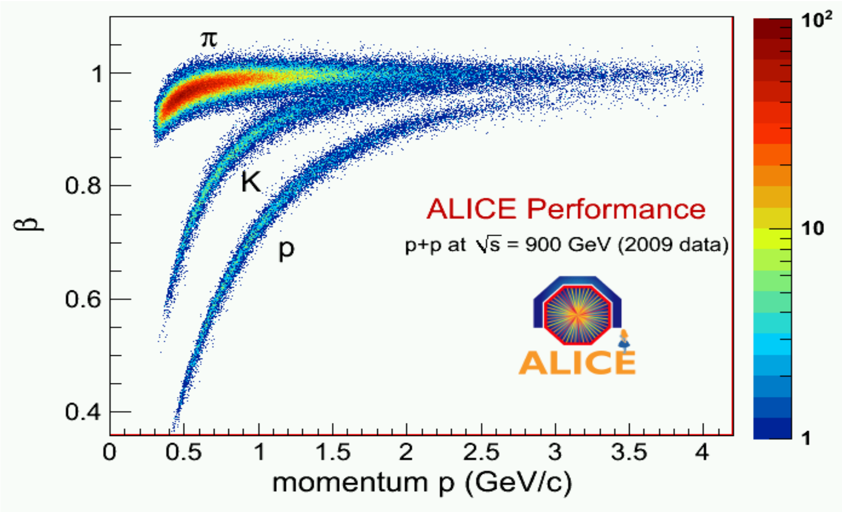
- Measure the time of flight of charged particles, combined with the momentum and the length of flight track , obtain the mass of particles

$$\beta = \frac{v}{c} = \frac{L}{c \cdot t} \qquad \beta = \frac{p \cdot c}{E} = \frac{1}{\sqrt{\left(\frac{m \cdot c}{p}\right)^2 + 1}}$$

$$m = \frac{p}{c}\sqrt{\left(\frac{c \cdot t}{L}\right)^2 - 1}$$

- $p - \beta \qquad p \uparrow, \ v \to c,$

$$\beta \to 1$$



TOF PID

- Comparison between measured and expected time:

$$t^{i}{}_{predict} = \frac{L}{c \cdot \beta_i}, \quad \beta_i = \frac{|\vec{p}|c}{E_i}, \quad E_i = \sqrt{m_i^2 + p^2}$$

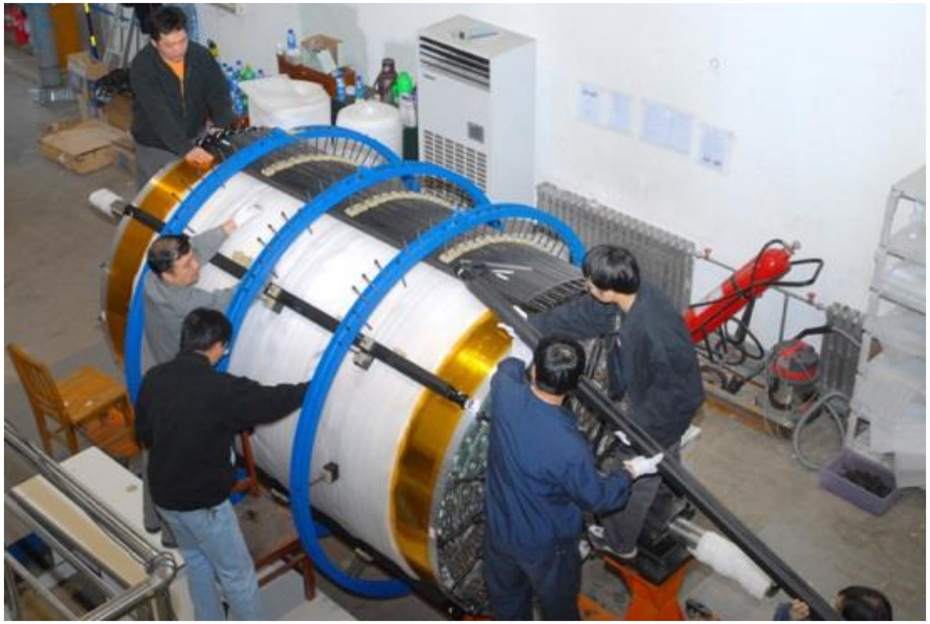
$$\chi = \frac{\Delta t}{\sigma} = \frac{t_{measure} - t^{i}_{predict}}{\sigma}$$ ➔ Normal distribution

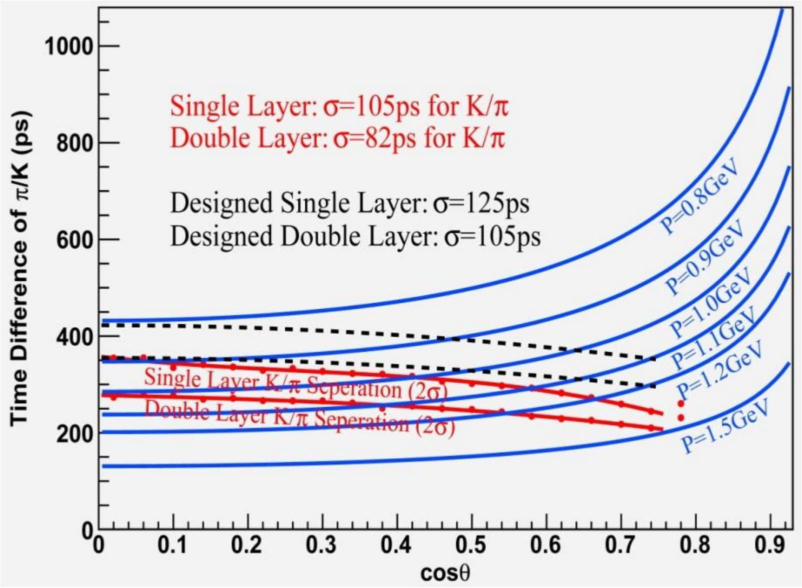
$$n_{TOF} = \frac{|t_A - t_B|}{\sigma_{TOF}} = \frac{Lc}{2p^2 \sigma_{TOF}} |m_A^2 - m_B^2|$$

- Particle separation power of TOF depends on:
  - The flight time difference between different species particles with same momentum.
  - Time resolution

Scintillation TOF

- Scintillator bar coupled with PMT
  - Good time resolution
  - PMT under strong magnetic field
  - Increase of granularity





Multi-gap Resistive Plate Chamber(MRPC)

- MRPC-TOF

Charged particle → Primary ionization → Avalanche → Induced signal

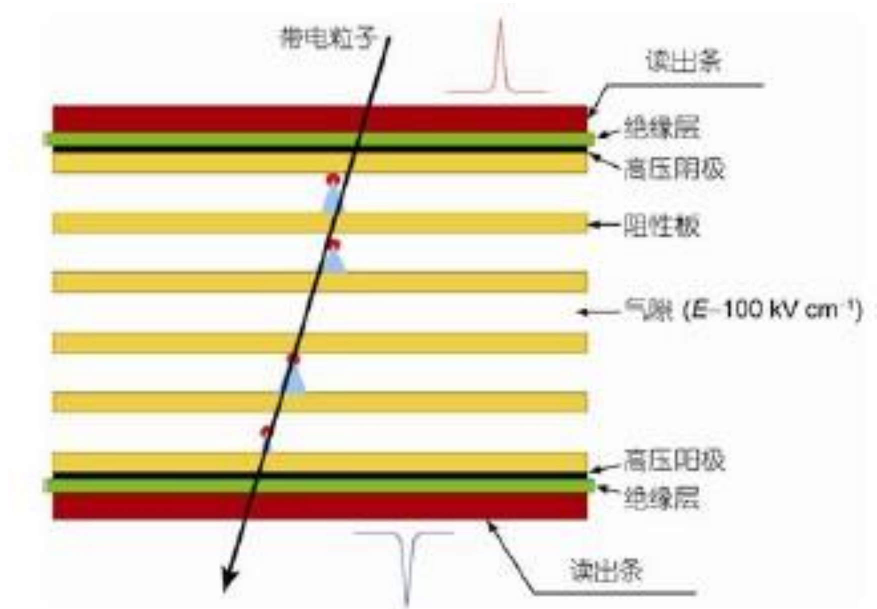
- Readout of scintillator is expensive, RPC is much cheaper.
- The RPC design was improved by Multi-gap RPC:
  - Reducing gap sizes

    restrict fluctuation of drift time

    improve time resolution
  - Increasing the electric field

    sum of the induced signals

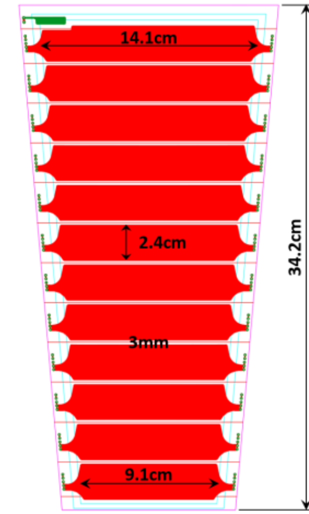
    good detection efficiency

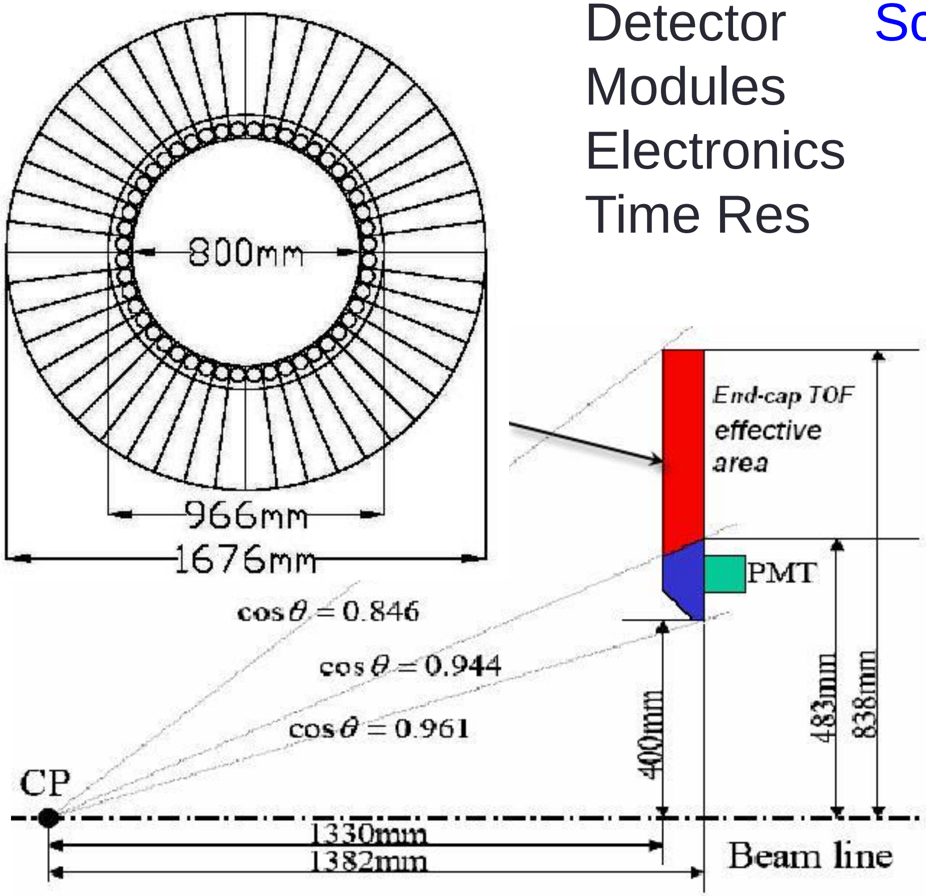


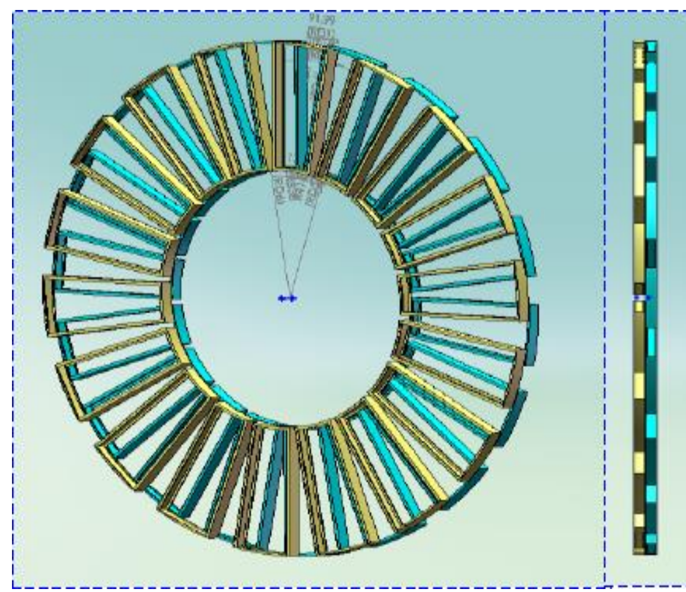
MRPC-TOF @ BESIII

- Scintillation TOF => MRPC TOF

	OLD	NEW
Detector	Scintillator	MRPC
Modules	96	72
Electronics	96	72×12×2=1728
Time Res	138ps	< 80~100ps

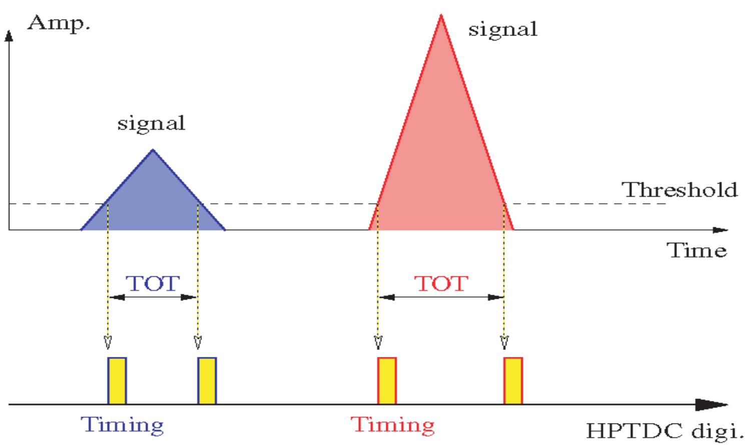


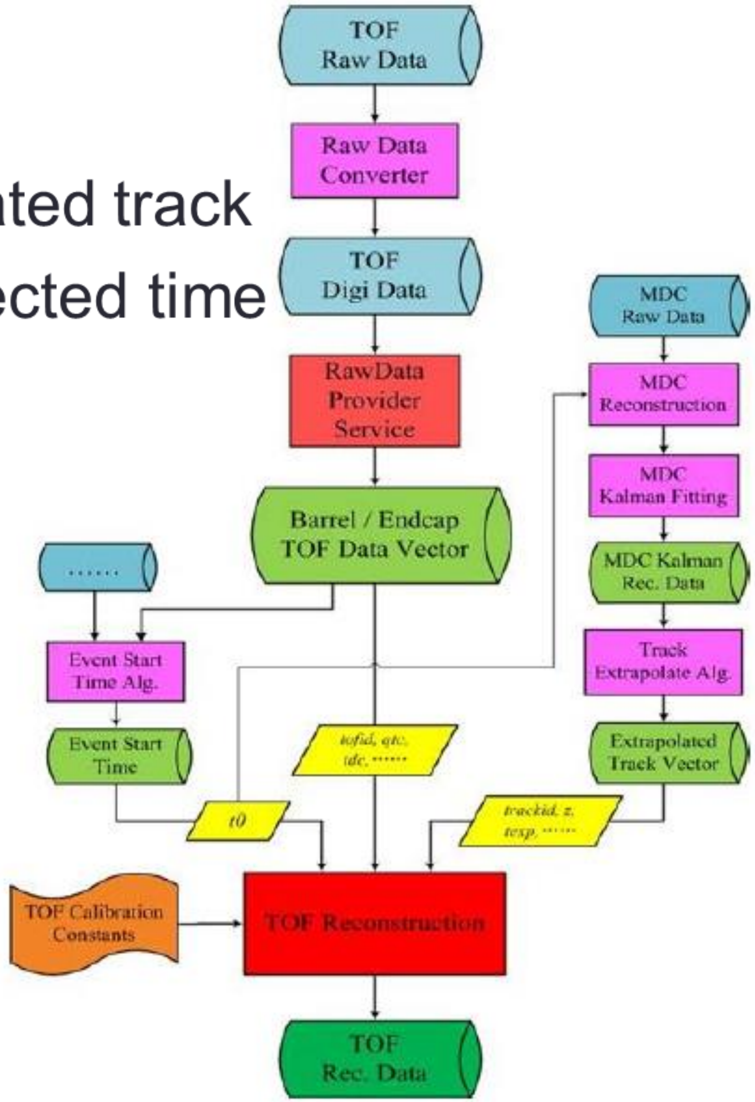




MRPC Endcap TOF Reconstruction

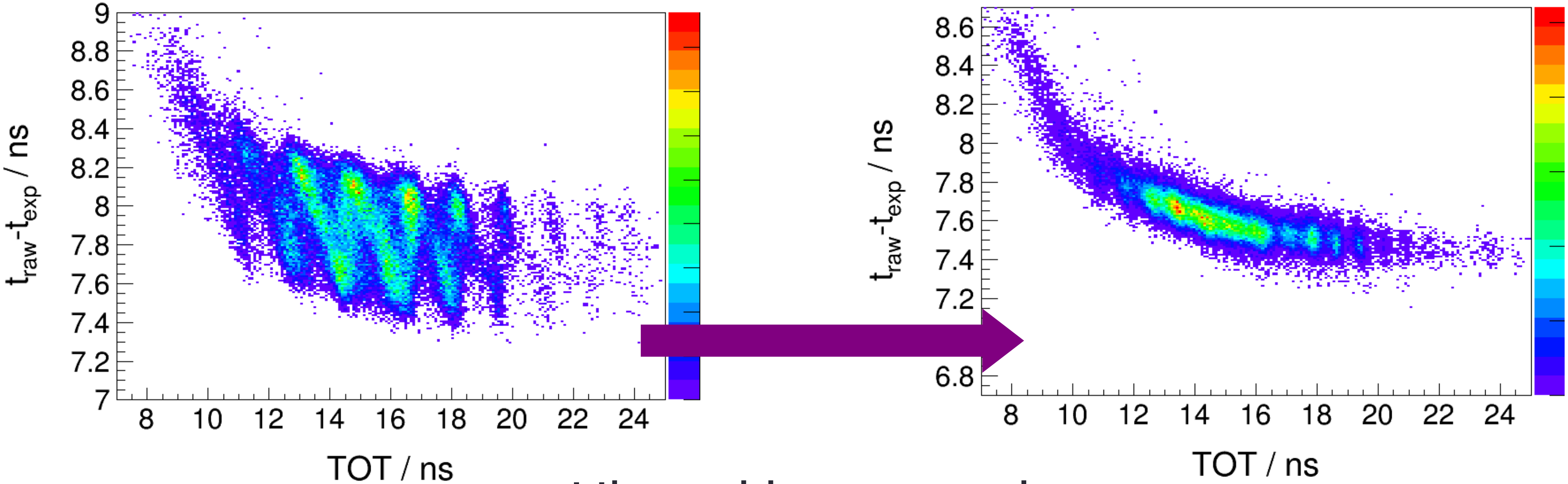
- Event Start Time t_0
- MDC Reconstruction ➔ Extrapolated track
  - Momentum, path length → expected time
  - Hit position
- TOF Raw Data
  - Leading time $t_{leading}$
  - Time-over-threshold (TOT)





Time Walk (Time Slewing)

- Measured raw time depend on hit position
- Multi-peak TOT partly depend on hit position



Hit position correction

MRPC TOF Calibration

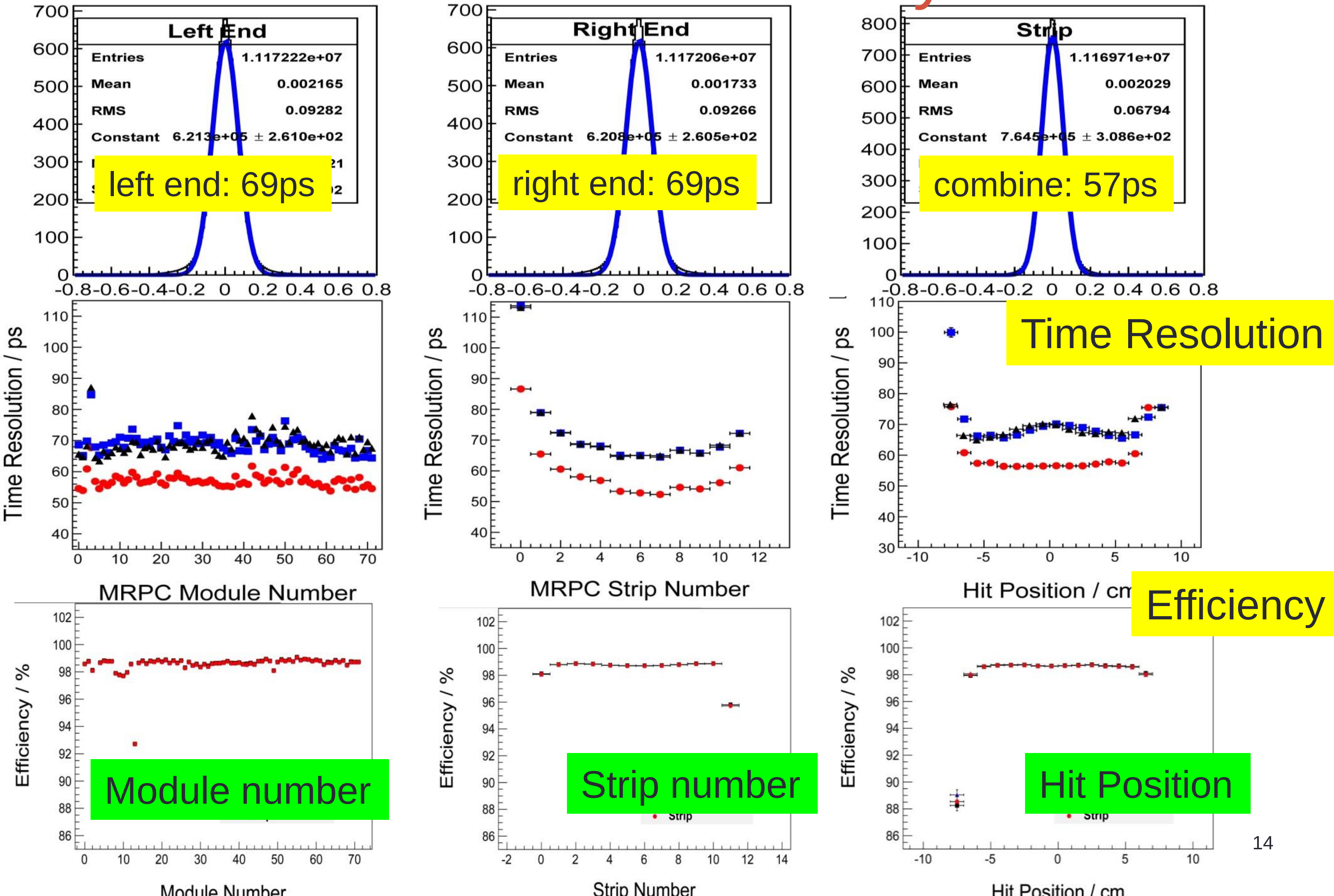
- Bhabha events are used for calibration sample
- Empirical calibration function for single end of strip

$$t_{corr} = p_0 + \frac{p_1 + p_2 \cdot z}{\sqrt{Q}} + \frac{p_3 + p_4 \cdot z}{Q} + (p_5 + p_6 \cdot z) \cdot Q + p_7 \cdot Q^2 + p_8 \cdot Q^3 + p_9 \cdot Q^4 + p_{10} \cdot z + p_{11} \cdot z^2 + p_{12} \cdot z^3$$

- Empirical calibration function for strip

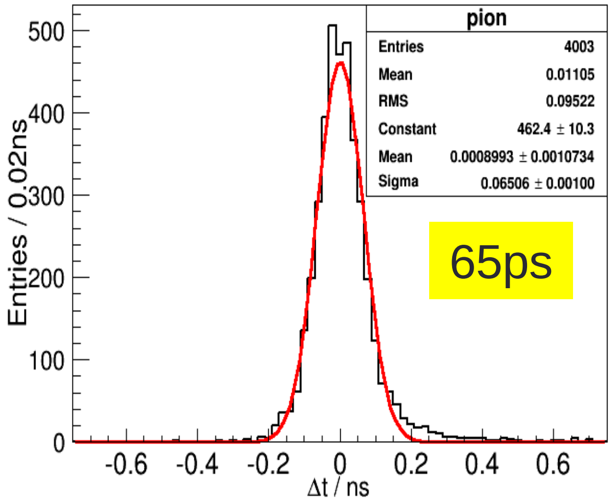
$$t_{corr}^{combine} = \frac{1}{2}(t_{corr}^{left} + t_{corr}^{right})$$

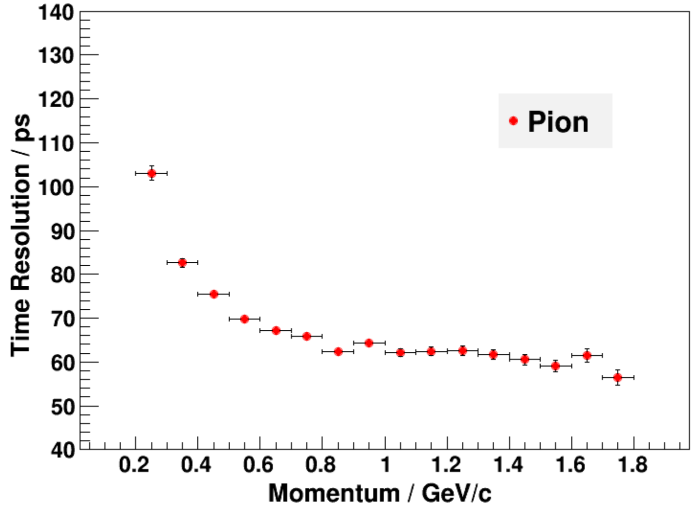
Time Resolution and Efficiency of Bhabha



Time Resolution for π

- Scintillator ETOF: 138 ps
- Designed Target of MRPC ETOF: 80~100 ps
- BESIII: 65ps





Accelator	Detector	Time Resolution(π)
RHIC	STAR	80ps
LHC	ALICE	86ps (Without t0)
BEPCII	BESIII	**65ps**

Summary

- Particle identification is crucial
- MRPC TOF: good time resolution, high efficiency and low cost
- Offline data processing of MRPC ETOF @ BESIII
  - Empirical calibration function.
  - The time resolution of Bhabha is 57ps.
  - The time resolution of 1.0 GeV/c pion achieved 65 ps.

Thank you !