Alignment of the BESIII MRPC Endcap TOF system

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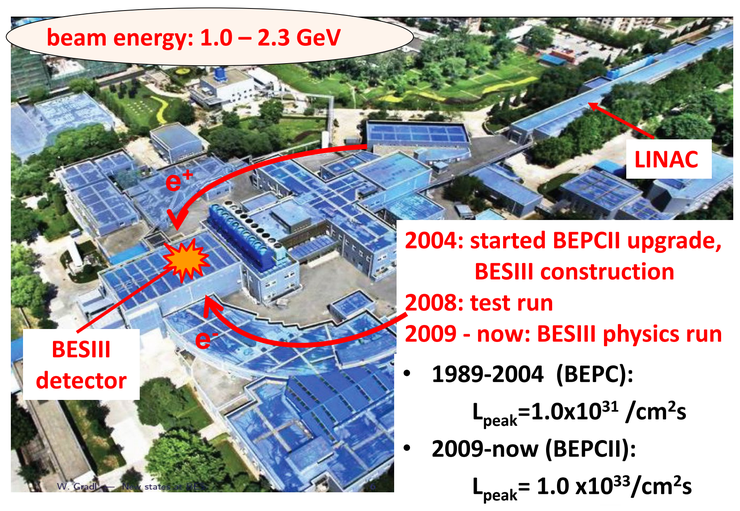
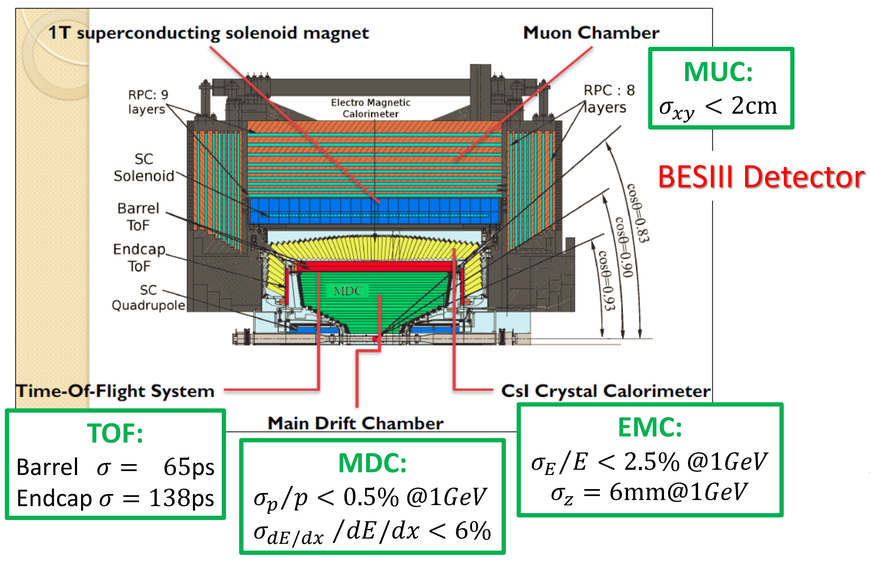
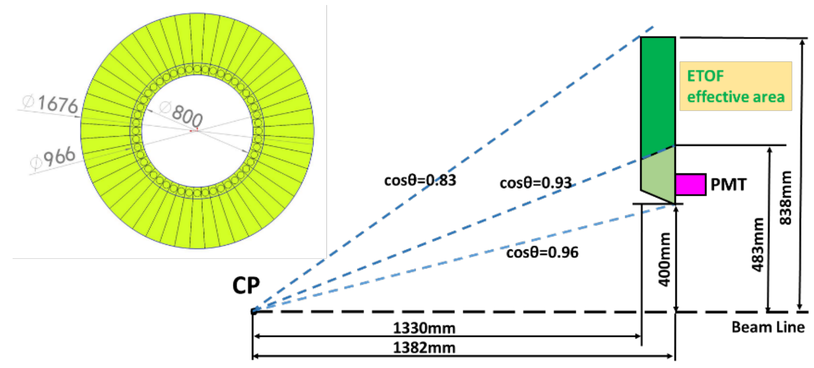


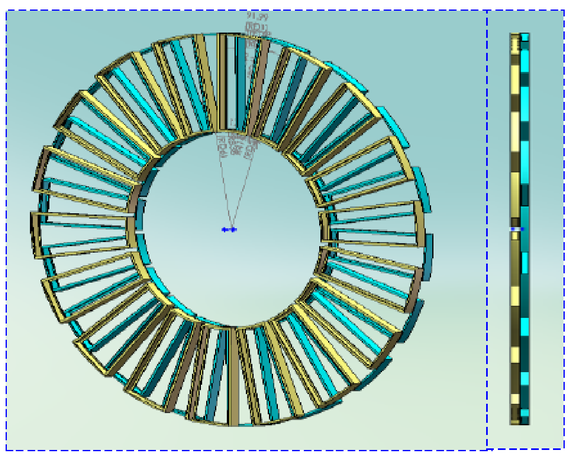
- 2004: started BEPCII upgrade, BESIII construction
- 2008: test run
- 2009 - now: BESIII physics run
- 1989-2004 (BEPC): L_{peak}=1.0x10^{31} /cm^{2}s
- 2009-now (BEPCII): L_{peak}= 1.0 x10^{33}/cm^{2}s

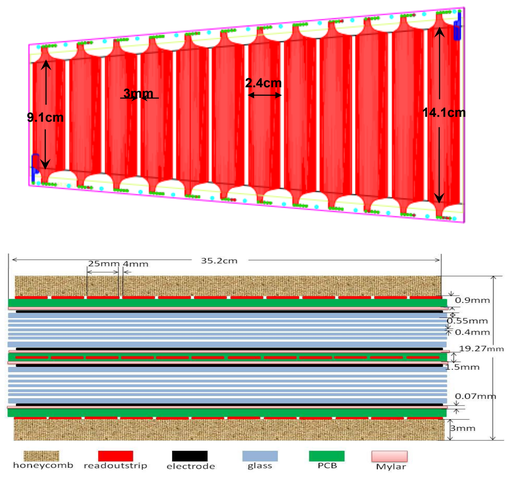
Beijing Electron Positron Collider(BEPC)



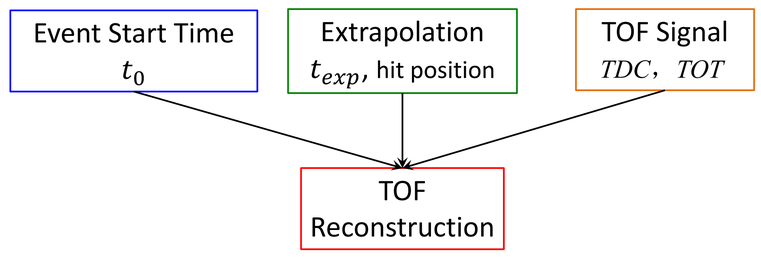
- Old BESIII endcap TOF:
  Two end caps of 48 scintillator BC404 + PMT R5924
  Time resolution: 138ps for pion@1GeV
- Target of MRPC endcap TOF upgrade:
  - ✓ Higher granularity
  - ✓ Better time resolution: overall time resolution 80ps for 1GeV/c muons.





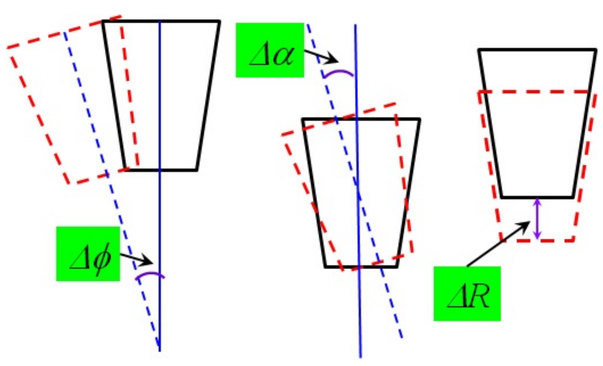


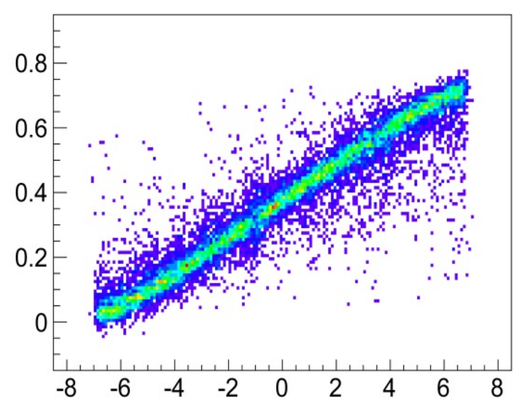
- Each TOF ring: 36 over-lapping MRPCs, no dead zone for particle identification
- 12 readout strips/module, double ends readout, 1728 channels
- Gas gap: 2×6 with thickness 0.22mm
- Resistive plate: floating glass
- Total thickness ~20mm

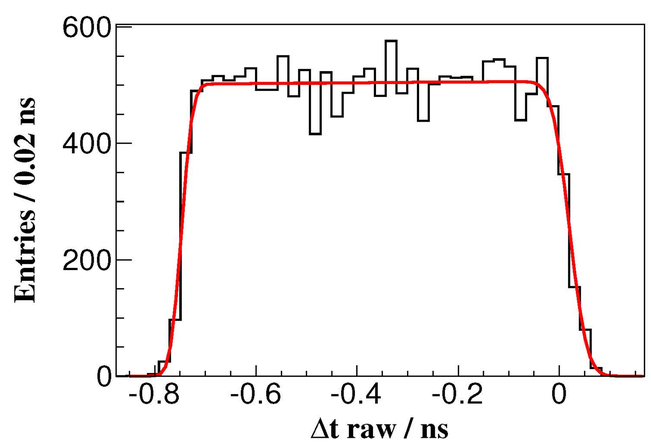


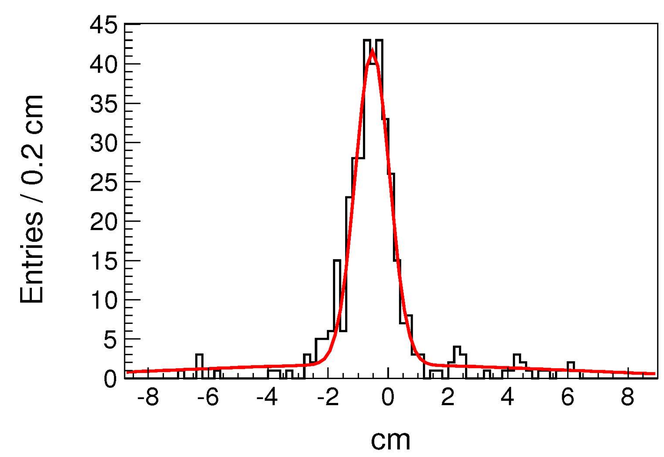
- Accurate alignment of MRPC end cap TOF is essential for particle identification in physics analysis.
- Each MRPC module together with FEE is mounted on the end cap of electromagnetic calorimeter(EMC).
- To ensure the installation position of each MRPC match the detector's design precisely, marking on the end cap EMC and pre-assembly of each MRPC are implemented.
- An offline alignment using Bhabha events is performed in addition to the initial survey and corrections for the mechanical effects.
- Alignment of longitudinal position of the detector is not considered in this study.
- 3 variables are defined for the alignment of the detector in transverse plane.

$$t^1_{raw} = \frac{z}{v_{eff}}$$
$$t^2_{raw} = \frac{l-z}{v_{eff}}$$
$$\frac{t^1_{raw} - t^2_{raw}}{2} = \frac{1}{v_{eff}} \cdot z - \frac{l}{2v_{eff}}$$

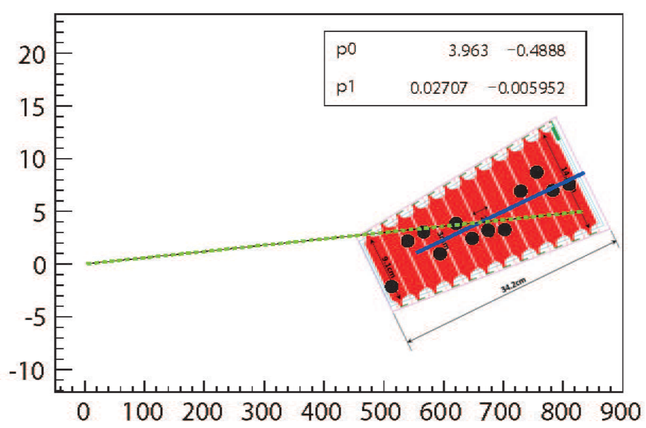


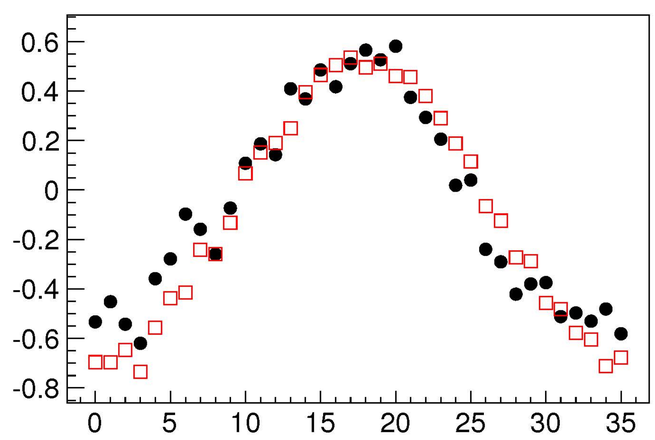


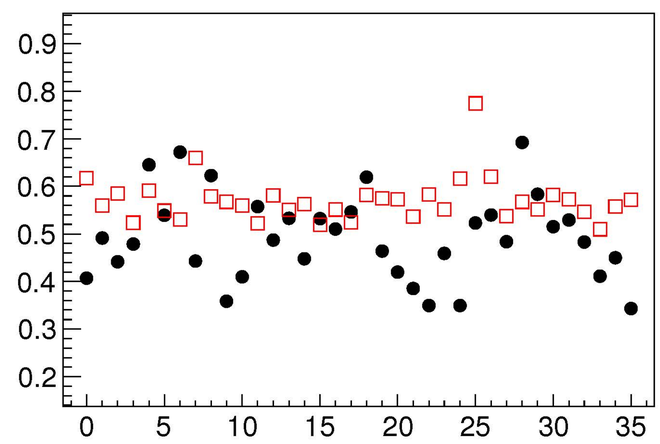




- The difference between the two raw measured times readout from two ends of one strip is proportional to the hit position along the strip with a factor of reciprocal of effective velocity of the induced signal propagation in the strip.
- The charged track extrapolation from MDC to designed end cap TOF is based on a reliable algorithm using the designed position of the detector.
- Alignment of the MRPC end cap TOF is based on the exploration of the relationship between the raw time difference and extrapolated hit position.
- The raw time difference is fitted using one order polynomial and two error functions which is describing the time fluctuation.
- The middle point of the time difference of each strip represents the real one of the strip which is defined as 0 along the strip, the deviation of the installation position could be expressed as extrapolated hit position which is corresponding the middle point of the time difference.



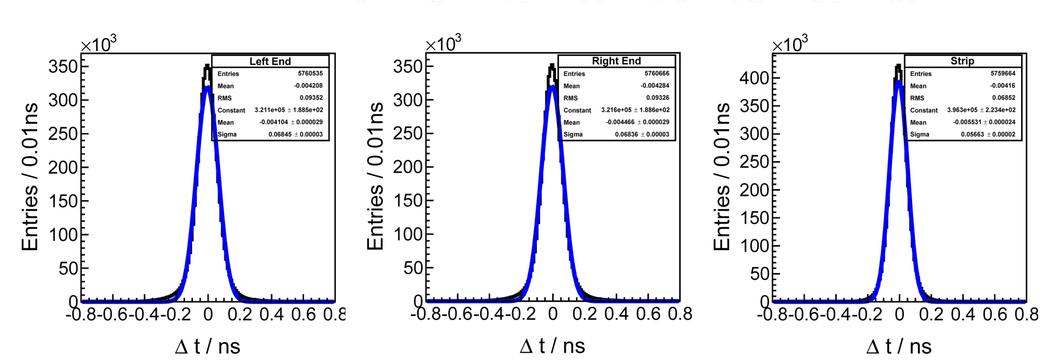


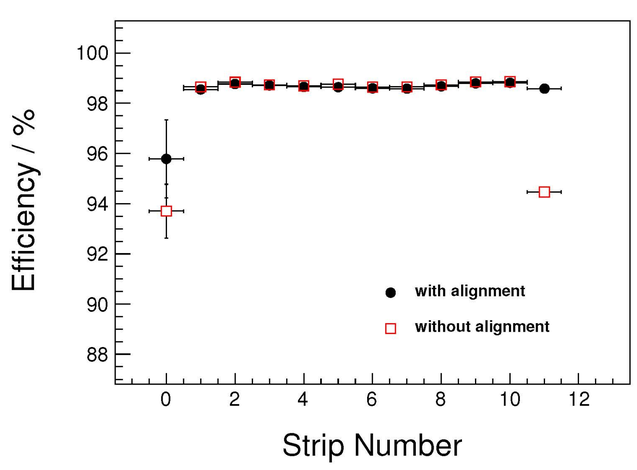


- Using the extrapolated hit position of real middle point of each strip, the position of each module is fitted, and the rotation angles relative to the ideal position and the axis of the symmetry are obtained.
- The east and west MRPC end caps are found 7mm higher and 0.45 degree rotation compared with the designed position.

The empirical function for calibration of single end of one strip:

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





- The endcap TOF detector of BESIII has been upgraded with MRPC technology in the summer of 2015, began data taking in Dec. 2015.
- An offline alignment using the real data for the MRPC end cap TOF has been performed.
- The installation positions of each modules are extracted using the middle points of the raw measured time differences of each strip.
- With the empirical calibration function, the time resolution of MRPC end cap TOF of BESIII has been achieved 57ps, and the efficiency of reconstruction is over 98% for electrons in Bhabha events.